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NEW YORK'S MARINE FISHERIES: CHANGING NEEDS IN A CHANGING ENVIRONMENT[1]

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ABSTRACT

Marine fisheries throughout the world have undergone tremendous changes over the past quarter-century. The situation in New York is typical. Increased pressure from foreign fishing fleets, changing domestic emphasis from commercial to recreational fishing and a changing marine environment (from natural as well as man-made causes) are producing changes in species composition in some ecosystems and in the availability and (and usability) of a number of food species. Mercury, PCB's and other pollutants have threatened the usefulness of several species. Pollution from domestic wastes has forced the closure of productive shellfish grounds. The possibility of offshore drilling for oil and gas poses a serious dilemma for coastal zone managers and fisheries managers. The increase in the number of marine anglers has put heavy pressure on several fish stocks. New management programs are suggested to bring our present fisheries programs into line with technological, social and environmental changes.

World-wide conditions have changed so much in the past few decades that fishing has become a focus of interest in the world struggle for food and economic viability (McHugh, 1976). And, with increasing populations in the Western World with more spendable income and more leisure time, fishing as a recreational activity today out-harvests many of the traditional commercial fisheries. Compounding the situation are environmental changes that combine with the fishing activities to produce changes in a number of ecosystems. Increased pressure from foreign fishing fleets, changing domestic pressure from commercial to recreational fishing, and a changing marine environment (from natural as well as man-made causes) have changed species composition in some ecosystems and the availability and marketability of a number of food species. All of these changes have had an impact on New York's marine fisheries.

[1] Contribution No. 77-4 of the Division of Marine and Coastal resources. This paper is based on a presentation at the 1973 Northeast Fish and Wildlife Conference at Mount Snow, Vt., but it also contains some more recent information.

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A major regulatory change that will have far-reaching implications for all coastal fisheries, including New York's, is the Federal "Fishery Conservation and Management Act of 1976" (the so-called 200-mile-limit bill) that was signed into law in April 1976 by the President. This act extends the exclusive fisheries jurisdiction of the United States to 200 miles (322 kilometers) in a zone contiguous to the territorial sea. Management of fisheries within the territorial sea, under the act, remains the responsibility of the coastal states. However, the Federal government can assume regulatory authority for a fishery within the territorial sea under certain circumstances if the state's fisheries management plans are deficient or lacking. It is important, therefore, to assess and document the marine fisheries of New York State as a forward-moving step toward formulating a management plan. That is the thrust of this paper.

CHANGING FISH ABUNDANCE AND FISHING EFFORT

The discussion of fish abundance included here is based primarily on the landings data published by the National Marine Fisheries Service and its predecessor agencies. While the published statistics for commercial fisheries landings provide a good general indicator of the trends in abundance of the species involved, they are not without some drawbacks. McHugh (1972) cautioned that inaccuracies creep in and the landings data do not take into consideration such factors as changes in demand, fishing effort, competition from other fisheries and other economic forces. Nevertheless, these data provide a useful yardstick by which to judge what is going on in the fisheries.

Most of the changes in fish abundance in the waters off the Northeast Coast are the result of both heavy fishing pressure and environmental changes. Several species have been affected (those mentioned in this paper are listed in Table 1), but the most dramatic example is the haddock. The salient features of the haddock fishery were described by Graham (1970). For decades it was a United States fishery on Georges Bank (off New England) and a few inshore banks. Some Canadian vessels took part in the fishery but most of the fleet hailed from New England ports, and trawlers from New York fished the bank during the summer. For nearly 25 years, the average annual United States landings amounted to 50,000 metric tons. In 1965, the Soviet Union entered the haddock fishery in force and the total annual landings increased dramatically to over 150,000 tons; the Canadians also increased their effort. To compound the situation, beginning in 1964, the Georges Bank haddock stocks have not had a successful year class to date. In 1972, United States landings of haddock were slightly more than 12,000 tons, and in 1975 they were down to 7,331 tons. The Soviet fleet directed its effort to other species off the East Coast of the United States and the

Table 1. Marine Shellfish and Finfish in New York's Fisheries

Common name	Scientific name
American oyster	*Crassostrea virginica*
Bay scallop	*Argopecten irradians*
Sea scallop	*Placopecten magellanicus*
Hard clam	*Mercenaria mercenaria*
Surf clam	*Spisula solidissima*
Short-finned squid	*Illex illecebrosus*
Long-finned squid	*Loligo pealei*
American lobster	*Homarus americanus*
Shortnose sturgeon	*Acipenser brevirostrum*
Atlantic sturgeon	*Acipenser oxyrhynchus*
American shad	*Alosa sapidissima*
Atlantic menhaden	*Brevoortia tyrannus*
Goldfish	*Carassius auratus*
Atlanitc cod	*Gadus morhua*
Haddock	*Melanogrammus aeglefinus*
Silver hake	*Merluccius bilinearis*
Red hake	*Urophycis chuss*
Striped bass	*Morone saxatilis*
Bluefish	*Pomatomus saltatrix*
Scup	*Stenotomus chrysops*
Weakfish	*Cynoscion regalis*
Tautog	*Tautoga onitis*
Butterfish	*Peprilus triacanthus*
Summer flounder	*Paralichthys dentatus*
Southern flounder	*Paralichthys lethostigma*
Winter flounder	*Pseudopleuronectes americanus*

haddock has been placed under regulation including catch quotas by the International Commission for the Northwest Atlantic Fisheries.

Foreign Fishing Effort

The foreign fleets operating off the East Coast, particularly those of the Soviets, are impressive and incredibly efficient. They consist of a variety of trawlers (including large factory ships) and support vessels (Jensen, 1971) capable of sustained fishing operations in all parts of the world. At times, the fleets are visible from the shore off Westhampton (N.Y.) much to the annoyance of local fishermen and other citizens. A typical fleet is described in "Summary of Foreign Vessel Observations —February, 1976", issued by the National Marine Fisheries Service in Gloucester (Mass.) on March 16, 1976. The summary reports that in February 1976, a total of 117 individual foreign vessels were observed in the Middle Atlantic Bight (Cape Cod, Mass., to Cap Hatteras, N.C.); USSR (55), Poland (8), East Germany (12), Bulgaria (7), Romania (2), Cuba (3), West Germany (3), Spain (17), Japan (9) and Ireland (1). The fleets included fishing trawlers, factory ships, transports and support vessels.

At times the fleets have included vessels from Mexico, Venezuela, Korea, Norway, Scotland, United Kingdom and France. The Japanese,

Spaniards and Italians are increasing their effort off New York in a specialized fishery for squid. The Japanese trawlers were fishing for squid off New York and were keeping the by-catch of butterfish. These species are highly prized for food in Japan. Formerly, Japan had filled most of her requirements for squid in a productive fishery off the coast of Mauritania in Northwest Africa. The shift of the Japanese vessels to the waters in the offing of New York was prompted by Mauritania's extensions of her territorial waters with an accompanying limit on the Japanese fishery in its waters. The Japanese trawlers thus came into competition with New York's fishermen who landed 258 tons of squid and 5,620 tons of butterfish in 1975.

Domestic Fishing Effort

This review of the domestic fisheries in New York's Marine District (Figure 1) is for the period 1948 through 1972. Some landings data through 1975 are included as they were available. The starting point, 1948, was chosen since it seemed that this marked the end of the socio-economic upheaval of the World War II era.

The domestic fishing effort in New York's marine fisheries is made up of a declining commercial segment and a rapidly rising recreational segment. Commercial landings at New York ports in 1948 were 58,821 tons and by 1954 they were 62,041 tons. Since then, however, they have declined steadily and in 1975 amounted only to 16,818 tons. The units required to make these catches are shown in Figure 2. (Gear data more recent than 1972 were not available when this paper was written.)

The number of vessels (defined by the National Marine Fisheries Service as craft of 5 net tons or larger capacity) in New York's commercial fishing fleet had been fairly static during the period from 1948 through 1972; it rose to a high of 272 in 1964 and then declined to 168 in 1972. The number of boats (defined as craft of less than 5 net tons capacity) had declined markedly in the middle 1950's and then began to increase until, in 1972, it was nearly the same as it had been a quarter-century before—3,912 boats. The larger craft (vessels) are more expensive to build, operate and insure than the boats. Because of their larger size and greater hold capacity, however, vessels are more mobile and can spend more days fishing farther offshore. But offshore they must compete with the foreign fleets. In contrast, it is easier for the boats to make capacity trips in the near-shore waters where they are not in competition with the large, efficient foreign fleets.

Figure 2 also shows a decline in units of gear fished except for shellfish rakes. The increasing importance of the shellfish industry in New York, especially that for the hard clam is the result of both economics and the abundance of the resource. A bayman can operate from a small, out-

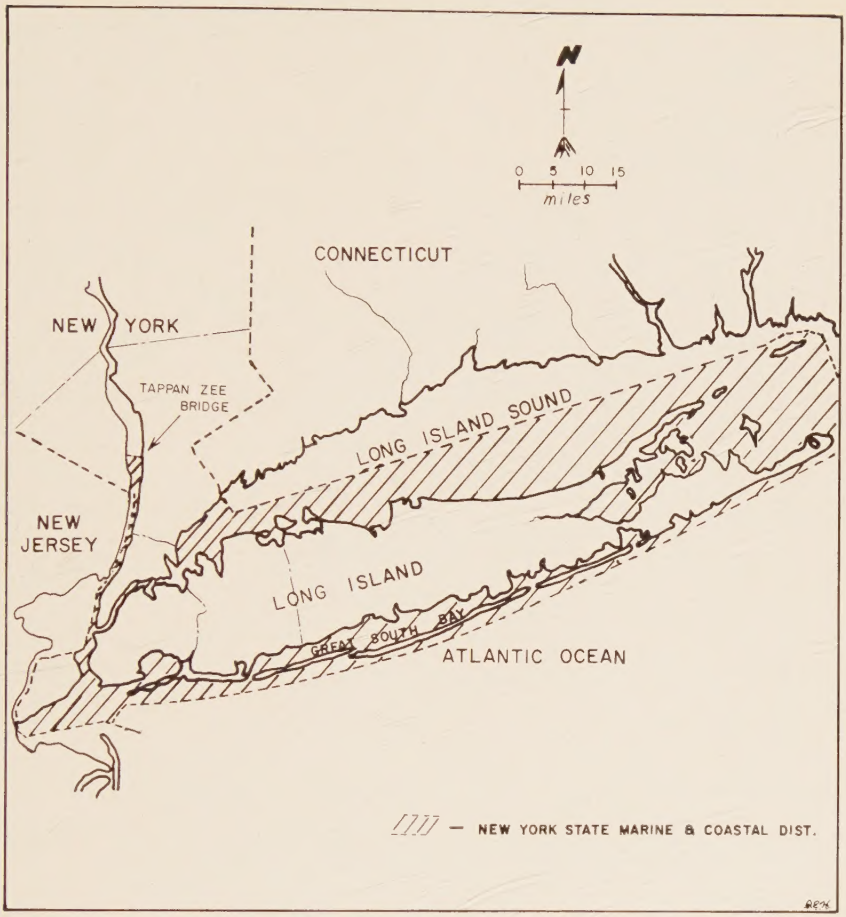

Figure 1. The New York State Marine and Coastal District comprises the waters of the Atlantic Ocean within 3 nautical miles from the coast and all other tidal waters within the State including the Hudson River up to the Tappan Zee Bridge.

board-powered skiff with rakes or tongs to harvest the clams, all at relatively low capital outlay. The abundance of the hard clam has held up quite well over the past 25 years, as has the rate of harvest (Figure 3), despite the decline of certified (i.e., unpolluted) waters available to the fisherman (Jensen, 1974d).

There has been a change in the kinds of gear used in the finfisheries during the period 1948-1972. The number of pound nets fished in New York's Marine District now is about half of what it had been at the start of the period. The effectiveness of such stationary gear depends on the abundance and movements of near-shore fishes. When these species

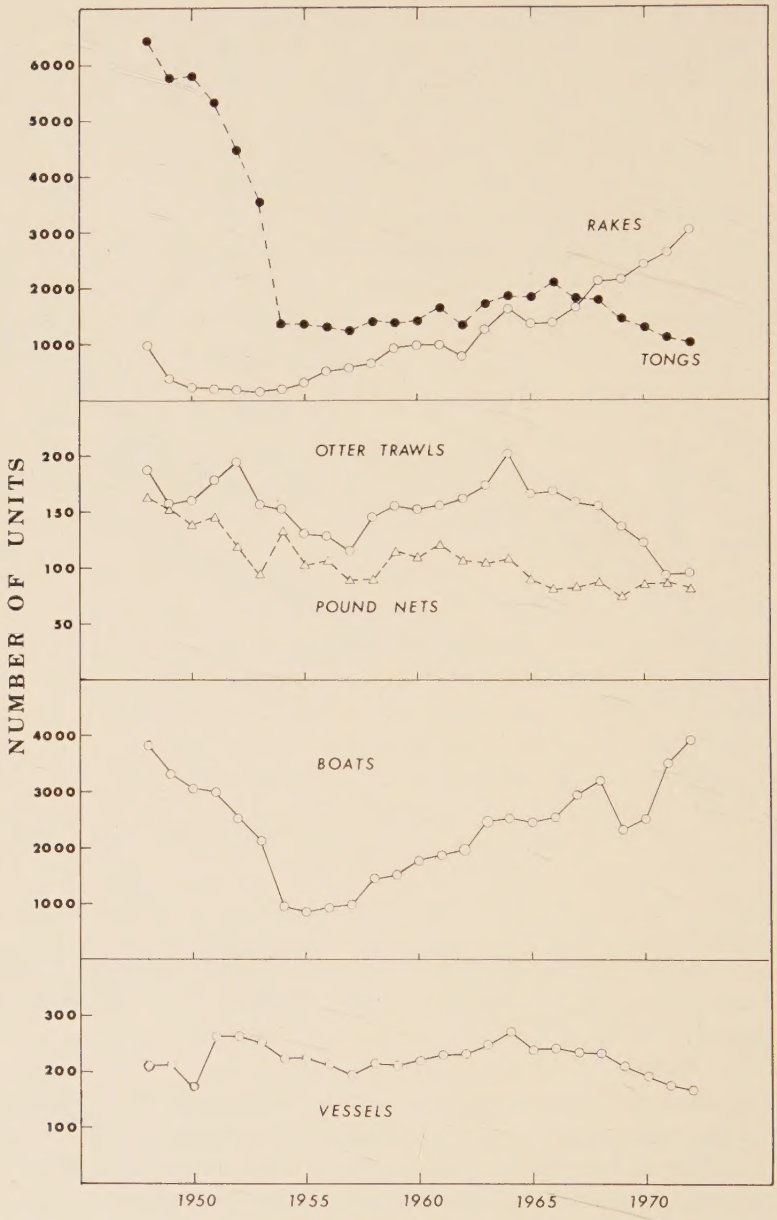

Figure 2. The units of gear in New York's commercial marine fisheries declined during the past quarter-century except for the numbers of rakes and tongs. (See text for definitions of boats and vessels)

are in low abundance, or move farther from shore because of natural or man-caused environmental changes, pound net catches decline. In

Figure 3. Landings of hard clams (meats) increased steadily during the 20 years prior to 1973, a result of greatly increased fishing effort and increased abundance of clams.

addition, pound nets are vulnerable to damage from storms and are expensive to repair and maintain. Similarly, the number of otter trawls today is half of what it had been. Both kinds of gear had declined in number during the middle 1950's and early 1960's but, although the number of otter trawls then remained fairly steady into the late 1960's the number of pound nets continued to decline.

The most marked decline in units of fishing gear is demonstrated by the haul seines (Figure 4). These nets are used to take striped bass, bluefish, scup and weakfish. Over the past 25 years, the number of haul seines has declined to one-fifth of what it had been.

The number of fishermen reported in New York's fisheries (Figure 5) has followed the same sort of trend as has the number of units of fishing gear, including vessels and boats. There has been a general decline of fishermen on vessels (as might be expected with the decline of vessels) and an initial decline followed by an increase of fishermen on boats. This

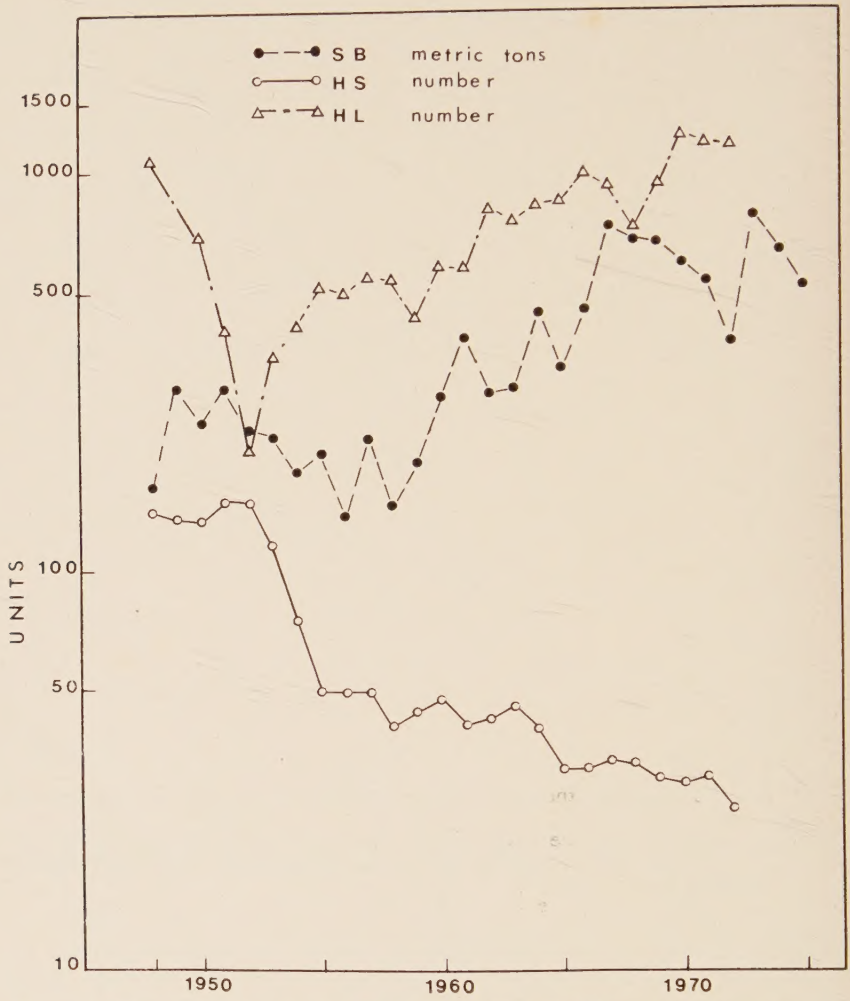

Figure 4. The rising trend of striped bass (SB) landings indicates increased abundance of the species and increased effort from anglers fishing with hand lines (HL), i.e., rod and reel, who sold their catches to dealers and restaurants. The number of haul seines (HS), the principal commercial gear in the striped bass fishery, declined steadily.

latter trend probably indicates the change in, and increasing importance of, the hard clam industry where boats are the principal craft.

All of the indicators discussed here—fishermen, fishing craft and gear—suggest a reduction in fishing effort in the State's marine fisheries. Unfortunately, they can only serve as indicators since data showing catch-per-unit-effort (e.g., hours fished) are not available. It seems safe to assume, however, that indeed there has been a real decline in commercial effort during the past quarter century.

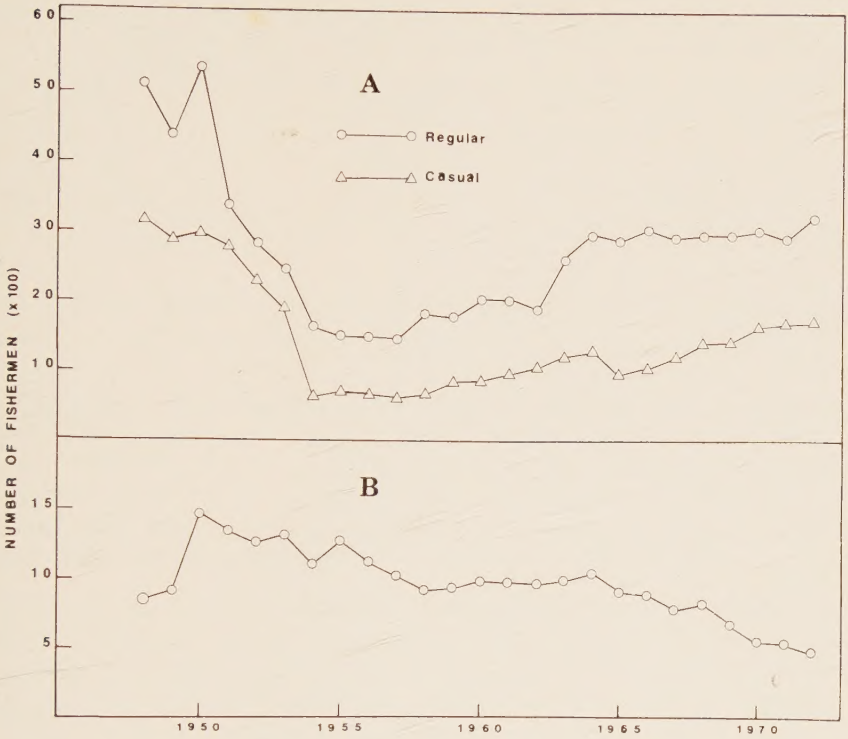

Figure 5. Trends in the number of commercial fishermen in New York's marine fisheries reflect the changes in the kinds of craft used. The number of fishermen on boats (A) increased, while the number on vessels (B) declined with the decline in the number of these larger craft. The National Marine Fisheries Service defines "regular fishermen" as those who receive more than half of their annual income from fishing, "casual fishermen" as those who receive less than half of their annual income from fishing.

The fluctuations in both commercial landings and apparent abundance of a variety of species of shellfish and finfish in the marine fisheries of New York have been documented by McHugh (1972). Most of the species have shown a decrease in landings over the past century. Some of the declines may have been the result of natural changes, some may have been the result of overfishing, and some may have been the result of reduced effort and market demand. McHugh (1972) stated that lack of management and overfishing probably are important causes of the deterioration of certain formerly important State fisheries. Unfortunately, he did not support these comments with data for effort, economics or consumer demand. He described the shift in importance of the several fisheries over the years (as evidenced by the reported landings) as a sort of "pulse fishing". That is, as the catches of one or a group

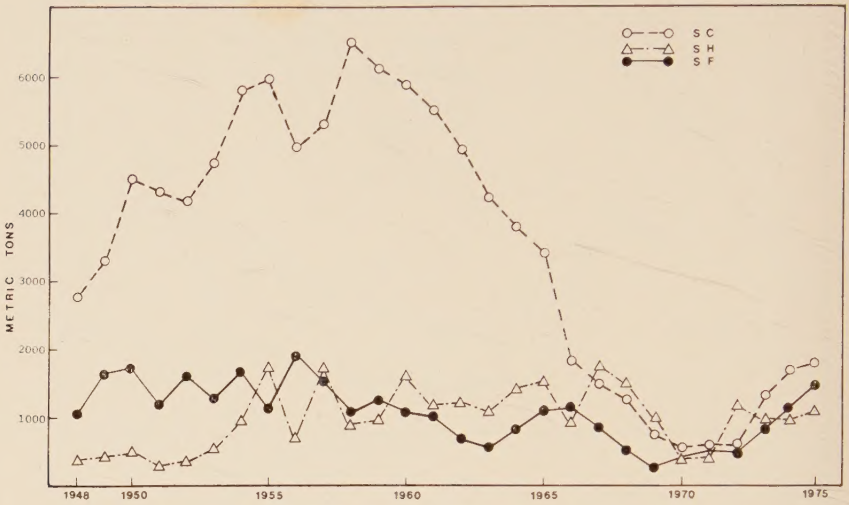

Figure 6. Trends in landings of scup (SC), silver hake (SH) and summer flounder (SF) in New York's commercial marine fisheries, 1948-1975.

of species declined, the industry shifted its effort to another more abundant species or group of species. (The Soviets and other foreign fleets operating off the coasts of the United States have been severely criticized by United States fishermen and fishery managers for engaging in pulse fishing to the detriment of stocks available to domestic vessels.)

A review of the principal species landed in New York during the period 1948-1975 shows a change in the kinds of fish and shellfish that made up the principal landings. At the beginning of the period, the chief food fishes were cod, haddock, butterfish, oysters and sea scallops. Today, the chief food fishes are flounders, bluefish, scup, striped bass, silver hake, hard clams, surf clams, and lobsters. Landings for three species affected by foreign effort are shown in Figure 6.

Recreational Fishery

A growing element in New York's marine fisheries—indeed, in the entire United States coastal fisheries—is the increasingly important recreational segment. The number of anglers fishing in marine waters off the Northeast Coast has increased from 1.2 million in 1960 to 1.7 million in 1970 (Jensen, 1974b). In 1970, anglers landed 12,157 tons of saltwater fishes. For several species the recreational catch exceeds the commercial catch by a factor of 1:20. For the North Atlantic Region (New England and New York combined; Deuel, 1973), the recreational catch was compared with the commercial catch for four species reported in the same year (Jensen, 1974b) as shown in Table 2. Since most of the fishes important in the recreational fishery also are important in the

Table 2. Comparative Catches (in metric tons) of Four Species by Recreational and Commercial Fishermen in the North Atlantic Region in 1970*

Species	Recreational	Commercial
Bluefish	22,748.7	727.3
Striped bass	20,790.9	636.4
Atlantic cod	16,185.0	16,909.1
Winter flounder	11,194.5	9,181.8

* From Jensen (1974b).

commercial fishery, the landings by recreational fishermen should be included in any consideration of changes in the abundance of a particular species.

Changes in the abundance of the summer flounder could well serve as a prime example of the angler/fish:abundance/environment interaction. The biology and recreational fishery of the species have been intensively studied in New York waters and are well documented (Poole, 1961, 1962, 1964; Briggs, 1962; Schaefer, 1966; Jensen, 1974c), particularly in Great South Bay. The recreational catch in the bay ranged between 800,000 and 1.8 million summer flounder per year from a population estimated to be from 3.9 to 5.5 million fish. In 1966, the catch in the bay declined to less than 300,000 from a population estimated to be 1.03 million fish. Schaefer (1966) concluded that variations in fishing success were directly dependent on variations in recruitment of young age groups of summer flounder into the population. The low rate of recruitment is believed to have been the result of some as-yet-unknown environmental factor.

The scup, also, is important in the State's recreational fisheries. Briggs (1968) showed that for the years 1964, 1965 and 1966 it represented 27.8, 44.6 and 35.7 per cent, respectively, of the species composition of fish caught by anglers in the inshore waters of eastern Long Island. He also showed that the estimated catch was as high (in 1965) as one million scup (approximately 600 tons of fish). The recreational landings reported for the North Atlantic Region in 1970 were 1,040 tons (Deuel, 1973) and the commercial landings for the same year and region were 865 tons.

CHANGING MARINE ENVIRONMENT

Changes in marine conditions involve a variety of facets of the environment, the more important of which are discussed.

Destruction of Wetlands

The environmental factors that cause changes in fish populations include alterations in the marine environment from deliberate human activities. A case in point is the loss of marine wetlands from dredging

and filling. The wetlands are important as spawning, nursery and feeding areas for many marine organisms including winter flounder, scup, menhaden, oysters, hard clams and bay scallops (Odum, 1961; Shuster, 1966; Spagnoli, 1971). Destruction of the wetlands reduces the abundance of the organisms that depend on the wetlands for some part of their life cycles.

O'Connor and Terry (1972) clearly described the destruction of marine wetlands in Nassau and Suffolk Counties (N.Y.). They stated that in 1972 there were 8,660 hectares of marine wetlands in the two counties and that 1,781 hectares had "disappeared" in the period between 1964 and that time. The loss resulted from dredging and filling for marinas, other businesses and homes. From 1961 to 1971, 57 million cubic meters of material were dredged and used to cover 2,926 hectares of land (O'Connor, 1973). Some of the dredge spoil was used to cover wetlands and some was used to cover productive underwater lands. Such filling on the underwater lands has detrimental effects on the shore-zone fishes found there (Briggs and O'Connor, 1971).

Pollution of Water

Pollution of the marine waters has caused changes in the usability of the fish and shellfish rather than actual changes in their abundance. One of the most direct forms of pollution is that from the discharge of sewage, street runoff and other waste products into the water courses. These discharges carry a variety of micro-organisms including human pathogens and many chemicals, heavy metals and petroleum products. The most direct effect of these substances is on the edible shellfish.

In 1975, the shellfish industry of New York was worth $17.6 million at the dockside, with hard clams, surf clams and oysters being the most valuable products in that order. Most of the hard clams were harvested from approximately 171,991 hectares of underwater land owned by the State of New York. (Some of the hard clams and most of the oysters were harvested on leased or privately-owned underwater lands. The surf clams were harvested in the Atlantic Ocean, some beyond the 4.8-kilometer limit of State jurisdiction.) About 24 per cent of the shellfish grounds were closed because the waters were polluted. Each year thousands of additional hectares are closed because they are polluted; in 1973, more than 5,261 hectares were closed (Jensen, 1974d). Although the shellfish remain alive in the polluted areas (some may even thrive because of the additional nutrients), they may not be harvested for human consumption. This removes potential products from the market and thus represents a waste of a natural resource. In addition, the waters must be marked with buoys and signs to identify them as closed to harvest and they must be patrolled by law enforcement officers. The

marking and patrolling are a further drain on the budgetary resources of the management agency. Thus, the shellfish in the polluted waters may be considered a negative fiscal resource.

Pesticides and Heavy Metals

The waters of New York's Marine District receive vast quantities of effluents in addition to sanitary wastes. Some of the effluents include industrial wastes from local manufacturing plants and from plants in nearby states. Many of the effluents include heavy metals such as copper, chromium, iron, nickel, lead, zinc and mercury. The Department of Environmental Conservation has been monitoring the bacterial quality of New York's shellfish since 1937. In 1966, the monitoring was expanded to include the testing of both shellfish and finfish for pesticide residues and, in 1970, further expanded to include testing for heavy metals.

The pesticides found in the marine waters include chlorinated hydrocarbons, DDT and its metabolites DDD and DDE, and dieldrin (Foehrenbach, 1972). In the past, DDT had been widely used in Long Island marine wetlands for the control of mosquitoes but now it is no longer used although it still persists in the soils of the wetlands. Dieldrin is found most commonly along the north shore of Long Island and probably is carried in runoff from lawns and grassfields of homes and estates where it is used to control grubs and other insect larvae. Fortunately, the residues of these pesticides are well below the limits set by the US Food and Drug Administration and are thought not to have any adverse short-term effects on marine organisms low in the food chain (Foehrenbach, 1972). The concentrations of DDT and its metabolites in the hard clam generally were less than 0.2 milligram per kilogram of organic tissue. The concentrations of dieldrin were less than 0.03 milligram per kilogram of organic tissue. The results of an extensive pesticide monitoring program revealed no clearly defined trends in pollution levels of these pesticides in shellfish (mostly hard clams) from New York waters for the period 1966-1972 (Butler, 1973).

Although the chlorinated hydrocarbons have been given the widest publicity in recent years, an "old-fashioned" pesticide—arsenic—has been found in three species of anadromous fishes in the Hudson River (Pakkala et al., 1972). Flesh of the shortnose sturgeon, the Atlantic sturgeon and the striped bass was found to contain residues of arsenic that may have entered the water from insect and plant biocides or from laundry detergents and enzyme pre-soaks. Ranges of arsenic levels in parts per million were: shortnose sturgeon, 0.40; Atlantic sturgeon, 0.080-0.20; and striped bass, 0.23-0.67. Pakkala et al. (1972) characterized the levels in the Hudson River as "high in arsenic content", compared with those

in other waters surveyed in the State, but suggested that this might have been a result of the size of the fish in the samples. Larger fish had higher levels, and most of the fish sampled in the Hudson River were large. The authors concluded that since the levels they found were well below the present Food and Drug Administration tolerance of 7.0 ppm for arsenic, there was no health hazard to persons who consumed the fish.

The flesh of striped bass and other fishes in the Hudson River have also been discovered to contain residues of polychlorinated biphenyls (PCBs). PCBs are chlorinated hydrocarbons used in a variety of industrial products, and enter the water by direct discharge as well as in the leachate from trash in landfills. Beal (1976) reported that analyses of fish from the Hudson River revealed levels of PCB's ". . . far in excess of the 5 parts per million (ppm) level set by the Food and Drug Administration as acceptable for human consumption." In August 1975, the Department of Environmental Conservation warned citizens against eating fish taken from the Hudson, especially long-lived species such as the striped bass. Then, in February 1976, the Department prohibited commercial fishing in this river except for Atlantic sturgeon more than 1.2 meters long, goldfish and American shad.

The tests for heavy metals have shown them to be at low to insignificant levels. However, the presence of mercury in a wide variety of marine organisms, many of which are consumed by humans as food, has been of considerable concern. The Food and Drug Administration established 0.5 ppm of mercury as an actionable level whereas previously it had been merely a guideline. The rationale was offered that ". . . the 0.5 ppm mercury figure is adequate, appropriate and necessary for the protection of the [fish] consuming public." (Kolbye, 1972). Research in the Department's laboratory at Stony Brook (Jensen and Foehrenbach, 1971) indicated that the level of mecury in six of eight organisms tested was below 0.15 ppm (Figure 7). The levels in the remaining organisms (striped bass and bluefish) reached, and in a few samples exceeded, 0.5 ppm. The levels were size-related with higher levels being associated with the larger fish.

A detailed study of bluefish and striped bass precisely determined the fish size-mercury level relationship (Alexander et al., 1973). Bluefish that weighed less than 2.4 kilograms contained less than 0.5 ppm of mercury and those weighing more than 5.6 kilograms contained more than 0.5 ppm. The mercury levels in fish between 2.4 and 5.6 kilograms varied above and below the 0.5 ppm limit. Striped bass that weighed less than 3.2 kilograms contained less than 0.5 ppm of mercury and those that weighed more than 5.7 kilograms contained more than 0.5 ppm. The mercury levels of fish between 3.2 and 5.7 kilograms also varied above and below the limit.

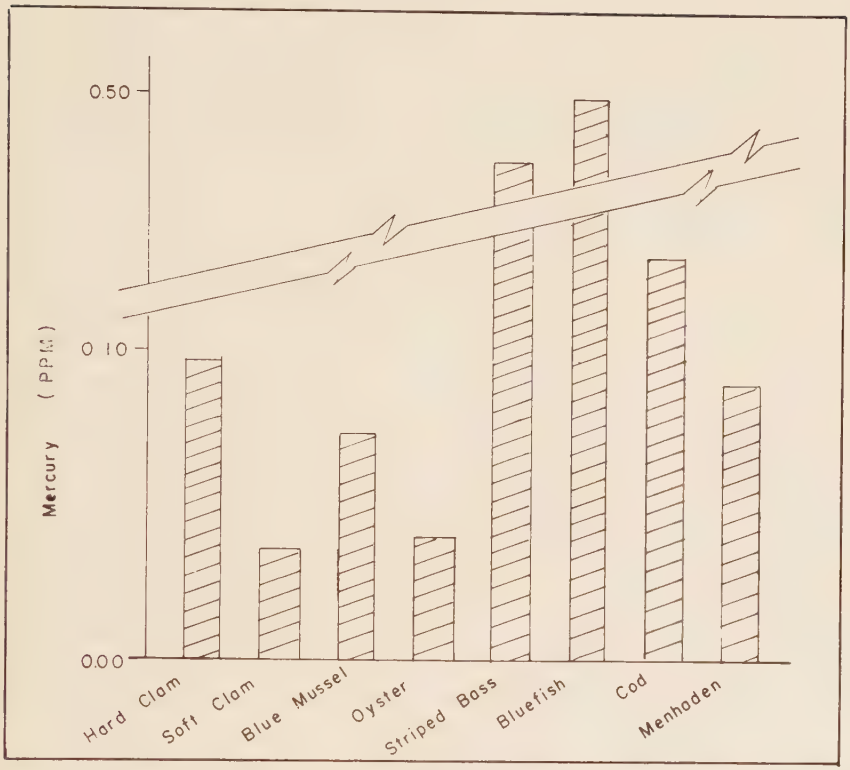

Figure 7. Levels of mercury in the flesh of representative marine organisms taken in New York waters. Except for those in striped bass and bluefish, all of the levels were well below the Food and Drug Administration limit of 0.50 part per million. (From Jensen and Foehrenbach, 1971)

The greatest amount of mercury in the marine environment is believed to be derived from the burning of coal (and perhaps, also, fuel oil) and the fallout of the combustion products (Joensuu, 1971). Some mercury is discharged with the wastes from chlor-alkali plants, pulp and paper mills and plastics factories. New York's Marine District receives little mercury directly in industrial wastes. However, the movements of water masses in the Atlantic Ocean and Long Island Sound, and the migration of fishes from other areas, probably account for the levels of mercury found in the studies.

Power Plants

The Marine District includes some of the most densely populated areas in the Northeast and also some of the most productive marine waters in the region. Thus, there is ample opportunity for environmental insults of a wide variety that can and do exert great stress on the marine eco-

systems. The thermal effects of steam electric generating stations offer good examples of such insults.

Reviews of steam electric stations in the Marine District (Jensen, 1970a, 1970b) showed that the total volume of heated water discharged by the plants was about 26.5 million liters per day with an average of about 12° Celsius added heat. The thermal effects are both local and regional. Locally, marine organisms, particularly fishes, are drawn in with the coolant water and impinged on screens designed to keep such large forms out of the station cooling system. The impinged animals die or are severely injured. Smaller organisms, phytoplankton and zooplankton (including fish eggs and larvae) are entrained in the coolant water. Many of them (up to 100 per cent in the summer) are killed by the heat and some by the shearing stresses of the water. During the winter, fish may remain in the thermal plume of the plant and provide good out-of-season sport for anglers. However, large numbers of these fish may be killed when the plants shut down temporarily and the thermal plume stops, thus subjecting the fish to cold shock.

The metabolic stresses, alterations of life cycles and artificiality of the thermal plume ecosystem affect both individuals and populations. A most noticeable effect involves disease conditions among fish in the thermal plume. The conditions include skin lesions, fin rot and skeletal malformations.

The regional effects of thermal additions are not as dramatic or as noticeable as the local effects, but in the long run they may be more damaging. In testimony before a Department hearing at Hauppauge (N.Y.) in 1971, Dr. Donald F. Squires of the Marine Sciences Research Center of the State University of New York at Stony Brook addressed himself to this problem. He estimated that, within the next 20 years, a regional warming of Long Island Sound on the order of 0.5° Celsius could result from the aggregate effect of the steam-electric plants in the western portion of the Sound. This could cause profound displacement of species.

Offshore Oil

The probability of exploratory and production drilling for oil and gas on the submerged lands of the Outer Continental Shelf off the East Coast presents a whole new spectrum of possible environmental changes. Seismic surveys and other geologic data indicate a number of areas off the East Coast that might prove to be petroleum provinces (Maher, 1971). Two sites off the Northeast Coast are of particular interest to New York's fisheries; one is the Baltimore Canyon Trough, the other is the Georges Bank Trough. Oil spills offshore at these sites could affect the local marine fauna and the beaches, marine wetlands and estuaries. Spills at

the shoreline, from oil handling facilities, could affect the coastal ecosystems to a greater extent.

The fisheries that may be impacted by oil spills, and the kinds and degrees of impact in the Marine District, have been reviewed earlier (Jensen, 1974b, 1976). For example, more than 40 species are sought by fishermen in the Marine District and the offshore waters. Fish of each of these could be killed or injured, depending on the stage in its life cycle that was touched by the oil. In addition, forage fishes and other food organisms also could be affected.

Although oil is most frequently thought of in conjunction with petroleum exploitation in the Outer Continental Shelf, other pollutants are generated in the drilling and production processes. These include drilling muds (mostly inorganics with some defoaming agents), brines of unknown and varying salinities, cleaning compounds from the rigs and platforms, and minor quantities of wastes accidently or deliberately dumped into the sea. The environmental effects of these other pollutants are not well known at the present time but are the subjects of research by independent laboratories as well as by government, university and industry laboratories.

It is clear that the environmental insult of spilled oil requires long, careful and intensive research. Blumer (1971) and Blumer et al. (1973) reported the great persistence of spilled oil and suggested that its half-life when spilled in the environment may be measured in years. Oil on the beaches may weather more rapidly than that on the open ocean but there may be more oil on the ocean with ". . . a potential for ecological damage that may be far greater than many authors have anticipated" (Blumer et al., 1973).

As with other marine pollutants, we must distinguish between the acute, usually short-term effects and the chronic, long-term effects. The first are easily demonstrated in the laboratory, the latter may not show up for years. Among the long-term effects is the tainting of edible marine organisms harvested for human food. Halstead (1970) pointed out that this is a world-wide problem and results in the products losing their market value. This is of great importance in the shellfish industry of New York State which supplies more than 50 per cent of the hard clams harvested in the United States (Jensen, 1974d). Finfish also can be tainted and thus detract from the full enjoyment of the sport for anglers who eat the fish they catch. Anglers have reported that striped bass caught in the Hudson River sometimes smelled like a burning rubber boot when they were being cooked and were inedible because of a lingering kerosene-like taste and smell. Presumably the bass absorb petroleum fractions in their tissues as they move through the East River and Upper Bay in the Hudson River estuary. These areas are surrounded by petro-

leum handling and refining facilities. A serious public health consequence of the ingestion of petroleum by marine organisms is the carcinogenic properties of some petroleum fractions (Halstead, 1970). The fractions not only are ingested but are concentrated—as are pesticides and heavy metals—in shellfish.

Changing Ocean Temperature

Natural, long-term, regional changes in ocean temperature affect the distribution and abundance of marine organisms (Edwards, 1965), much to the consternation of marine fishery managers. The waters off the Northeast Coast, including New York's Marine District, have exhibited generalized warming and cooling (Colton and Stoddard, 1973) over many decades although no cyclic pattern is apparent. The effect on marine organisms and the fisheries for them has been reported for the American lobster in Main (Dow, 1969) and in New York (Jensen, 1972a; and unpublished data). When the temperatures declined in Maine's coastal waters, the catches of lobsters declined. However, in New York waters during the same period, the catches of lobsters increased threefold over a 10-year interval.

CHANGING SOCIAL PRESSURES

The changing environment has inflicted a variety of stresses on the marine fisheries of New York and these have been compounded by changing social pressures. Perhaps the most forceful social pressure is that generated by recreational anglers. The population of saltwater anglers has boomed since World War II and their removal of the resources in many instances far exceeds that of the commercial fishermen. Alperin (1966) estimated that more than one million anglers fished in the Marine District each year and that the number increased by 6 per cent annually. A survey made by the National Marine Fisheries Service (Ridgely and Deuel, 1975) indicated that nearly 3 million persons participated in marine recreational finfishing and shellfishing in New York during the period from June 1973 to June 1974.

A comparison of catches made by saltwater anglers and commerical fishermen in the Northeast (Jensen, 1974b) showed that, for the bluefish and striped bass, the anglers caught 30 times more fish (by weight) than the commercial fishermen. In contrast, the catches of Atlantic cod were approximately the same for the two groups. (The Northeast Region includes New England and New York as described in the angler survey reported by Deuel, 1973.)

Considering New York's cod fishery separately, the recreational portion greatly exceeds the commercial portion both in participants and catch (Jensen, 1972b, 1974a). Personal observations and reports by

vessel captains and anglers indicate that the catch per day of cod on a party boat out of Montauk is between 1.4 and 2.3 tons on a good fishing trip and may be more than 4.5 tons on an exceptionally good trip. (Compare this with the average catch per day of about 1.5 tons made by a large commercial trawler out of Boston, Mass.) One very excellent trip took place in 1973 on which 50 patrons aboard the head boat *Peconic Queen II*, out of Montauk, caught a total of 900 cod which included 100 cod that weighed between 18 and 23 kilograms each and 10 that weighed over 23 kilograms. Using a conservative estimate of 7 kilograms as the average weight for the rest of the catch, the total for the day's fishing amounted to nearly 6 tons! The estimated total recreational catch of cod at Montauk is about 2,700 thousand tons per year. Additional angler catches of cod are landed seasonally at Freeport and Sheepshead Bay. (By comparison, New York's commercial catch of cod averaged 188 tons, annually, for the period 1969-1973.

In addition to the angler pressures on the resources in the simple removal of biomass, there also are pressures from angler groups to restrict the right to fish for certain species to selected segments of society. The striped bass is a good example. The State has no restrictions on the catching of striped bass, in either the recreational or commerical fishery, except for the minimum size limit of 40.6 centimeters in fork length. However, a number of angler groups, over the years, have requested legislation to make the striped bass a game fish in New York State and thus end the commercial fishery for the species.

During the period 1964-1973, 90 bills were introduced in the New York State Legislature to regulate the striped bass fishery (Ginter, 1974). Most of them were designed to make the bass a game fish. The arguments by proponents were based on the assertion that the commercial fishery, particularly the haul-seine fishery, was harmfully reducing the abundance of the species while the fish were available in the Marine District during their annual migrations. More recently, however, the proponents have abandoned the biological and fisheries management arguments and offer, instead, financial and sociological support for legislation. The Department has opposed the bills allegedly based on biological arguments since there is no evidence that the striped bass populations in New York waters are in any way threatened by the commercial fishery. In fact, with some minor variations the trend in New York landings has been upwards for many years (Figure 4), suggesting a growing population of the species. (The 1973 landings reached 760.9 tons—an all-time record for the State.) The Department took no position on the bills that were based solely on financial or sociological arguments. (The author discussed the striped bass situation in New York in detail at the Annual Meeting of the American Fisheries Society in

Orlando, Fla., in 1973, and the manuscript is in preparation for publication.)

Additional social pressures have included demands by anglers, boaters and other recreational users of the marine waters for restrictions on the commercial fishery for menhaden in Long Island Sound and for weakfish in Great South Bay. As a result, menhaden vessels now [1974] are prevented from fishing in certain embayments and the extreme western end of the Sound (see Section 13-0333 of the Environmental Conservation Law).

In 1974, a law was enacted by the Town of Islip regulating the taking of weakfish in marine waters bordering the town. The law was dismissed in court, however, as pre-empting the right of the State to control and manage the fisheries for migratory species.

In recent years, various citizen groups have been successful in having legislation enacted to restrict commerical fishing in certain parts of the Marine District. Data are not available to measure the effects, if any, of these various restrictive laws on the volume and species composition of the recreational, and the remaining commercial, fisheries or even on the ecology of the marine fishes.

Other social pressures have come about simply as a result of the rapid growth of communities around the Marine District and their demands for water-related services. The burgeoning numbers of boaters require marinas, for example, in which to keep their vessels, and, in many instances, construction of the marinas has resulted in the loss of marine wetlands with a consequent loss of their productivity for fish and other marine organisms. In addition, the illicit discharge of sanitary wastes, as well as the discharge of petroleum wastes from the boats, markedly lowers the quality of the water in the docks and anchorage areas (Cassin et al., 1971).

MANAGING THE RESOURCES

The changing environment requires the fishery manager to work with (or around) the several factors that are impinging on the fishery resources. Many purists regard this as professional weakness and demand that the environmental insults to be halted at once. This is a simplistic and highly idealistic approach, although none would argue that it is not, in the long run, desirable. The several management programs for New York's living marine resources include efforts for both shellfish and finfish. The programs are designed to recognize the purists' demands while working toward the managers' goals.

Shellfish Management

In 1965, New York State began a drive to clean up its lakes and

rivers, including the Hudson River and other streams that flow into the Marine District. The drive was started with monies from a one-billion-dollar Pure Waters Bond Act passed that year by the Legislature. In 1972, the Environmental Quality Bond Act was passed to supplement the funds of the first bond act. Both measures have brought about vast improvements in the quality of many waterways in the State but, unfortunately, not in the Marine District. Indeed, Mt. Pleasant and Bagley (1975) reported that:

> "The Atlantic Ocean-Long Island Sound Basin, particularly the waters immediately impacted by the City of New York, has not shown any measurable improvement. Organic and thermal wastes discharged contribute to depletion of dissolved oxygen and elevation of water temperature. Bacterial quality is also poor due to the current discharge of raw sewage and combined sewer overflows."

The important clam-producing waters of the Marine District, particularly Great South Bay, do not receive the vast amounts of sewage that discharge into the waters within New York City. Most of the bacterial and other pollutants impacting the Nassau-Suffolk portion of the Marine District result from street runoff following rainstorms and snow melt. Nevertheless, the bacterial load is sufficiently high to require the closure of many acres of valuable clam-producing bottom.

The construction of waste-water treatment facilities is an admirable program and will do much to remove a major source of microbial pollutants from the State's shellfish waters. Unfortunately, the treatment plants cannot solve the problem of the pollutants in street runoff. This can be a substantial vehicle for coliform and other bacteria. Analyses of the bacterial content of street and parking field runoff made in 1972 and 1973 indicated values (in terms of "most probable number per 100 milliliters") as high as 920,000 total coliform, 350,000 fecal coliform, 350,000 *E. coli* and 1.7 million fecal streptococcus (Redman, 1973; Jensen, 1974d). The Food and Drug Administration limit for total coliforms in shellfish waters is 70. In addition to microbes, street runoff carries with it pesticides, hydrocarbons and heavy metals, as well as additional nutrients in the form of animal feces (mostly from domestic dogs and cats) and plant fertilizers. The fertilizers are the excess from applications to home lawns and gardens and contribute to eutrophication of the bays.

The State's shellfish transplanting program is one management technique for using the clams in certain closed areas and making them a source of revenue to the clam diggers and, ultimately, the local economy (Jensen, 1975a). Briefly, the program functions this way. The clams on the closed grounds are harvested by a mechanical dredge under contract

to the State.[3] The harvested clams are moved to open waters, i.e., areas where the water quality meets the minimum standards of the National Shellfish Sanitation Program directed by the Food and Drug Administration and where shellfish may be harvested for direct human consumption. The clams are planted on State-owned bottom and remain there under State or Town surveillance for 30 days. At the end of this "cleansing" period, the clams are tested by Department personnel for bacterial indicators. If none is found, the grounds are opened to baymen who may harvest the clams with tongs or rakes. In the period 1964-1974, the State has directed or supervised the transplanting of a total of 215,613 bushels of hard clams, the principal species in the program (S. Hendrickson, personal communication). Although the transplant program does not alleviate or eliminate the bacterial pollution of the closed waters, it does not make the claims usable.

There is an alternative to the transplant program that also cleanses bacteria and other pollutants from shellfish. This is the process known as depuration. The State began a study in 1964 to evaluate the depuration process in a pilot-plant-size operation. Depuration involves placing shellfish from closed waters in baths of flowing, sterile seawater. The water may be sterilized by irradiating it under ultraviolet, germicidal lamps, or, as in the State project reported by MacMillan and Redman (1971), pumping it from a saltwater well that delivered water that was naturally sterile and of uniform, year-around salinity and temperature. After 48 hours in the depuration bath, hard clams were found to have purged themselves of coliform bacteria. Unfortunately, heavy metals, pesticides, radio-nuclides, viruses and, presumably, hydrocarbons are not removed by the process. Because of these shortcomings, the State has been reluctant to license commercial depuration plants. However, it does license (and closely supervise) a commercial plant that uses the depuration process to remove sand from soft clams for the steamed clam market. As with the transplant program, the depuration process works *with* the problem of polluted waters to make the shellfish usable.

In 1973, the Department sponsored legislation which encouraged the shellfish industry to make maximum use of the available clean shellfish waters. The legislation (Section 13-0316 of the Environmental Conservation Law) provides a license system for the operation of shellfish hatcheries. The license is made available for a fee of $100 to bona fide organizations and permits the holder to raise clams, oysters and other shellfish. A licensed hatchery may produce organisms for planting on

[3] In recent years, some Long Island towns have participated in the program using their own funds in combination with funds available under Federal Aid to Commercial Fisheries (PL 88-309) administered by the National Marine Fisheries Service and supervised by the State through the Department of Environmental Conservation.

its own grounds, or it may sell the organisms, donate them to scientific institutions or otherwise traffick in them. Such trafficking had heretofore been specifically forbidden in the law. In addition, this legislation clarified a previously misinterpreted law so that off-the-bottom (raft) culture of the shellfish now is permitted.

Finfish Management

Efforts to manage marine finfish in the State, unfortunately, have been uneven and spotty, and have often been put in force as the result of social and economic pressures rather than for conservation goals. Indeed, McHugh (1972) and Ginter (1974) have labeled the State's efforts as "mismanagement" although lack of management might be a more accurate term.

Subdivision 5 of Section 13-0333 of the Environmental Conservation Law, which restricts commerical menhaden seiners in Long Island Sound, is a case in point. It was enacted as the result of strong pressure from various citizen groups (and a few local municipalities) who objected to the presence of the vessels, to the commercial harvest of the menhaden and to the discharge from the vessels. The discharge is the effluent from the dewatering process that takes place during fishing operations for menhaden (Meyer, 1974) and contains menhaden scales, bits of fins and other tissue, and some oil from the fish. Proponents of the menhaden law argued that, in addition to preventing the abuses cited, the fish not caught by the seiners would provide additional food for striped bass and bluefish. Thus, it was argued, there would be increased numbers of the predatory fish sought by anglers. Opponents of the law argued that, unless large numbers of menhaden were harvested, the surplus would die off in the massive natural fish kills that take place almost every summer in Long Island Sound.

Though the law was enacted for the reasons noted, it may also protect some menhaden in Long Island Sound from over-exploitation by the large seine vessels, although there was no biological evidence that the species needed such protection. While the author was an observer aboard a seiner in the Sound in July 1975, I saw many large schools of menhaden that did not move out into the Sound beyond the buoy line that forms a sort of sanctuary for them under the menhaden law. Nevertheless, of those schools that were available to purse seines, the vessels were able to set around only about 20 per cent; the rest escaped simply because there were more schools in the water than the vessels were able to handle.

There are no catch limits on finfishes in the Marine District but there are minimum size limits for several species. Section 13-0339 of the Environmental Conservation Law names 11 species for which minimum

sizes are established for the commercial fishery; only three are also listed for the recreational fishery (summer flounder, southern flounder and striped bass). None of the size limits has any biological basis. For example, for each species the limit is well below the size at which the fish become sexually mature and spawn for the first time. From discussions with fishing industry representatives, it appears that the limits may have been established because they represent sizes of fish that the market considered desirable for sale to consumers.

The size limit for summer flounder originally was imposed only on the commercial fishery (John C. Poole, personal communication). Later, as a result of research by State fishery biologists, it was extended to include the recreational fishery (Schaefer, 1966; Jensen, 1974c). Here, the limit was imposed to insure continuous recruitment of young fish during the summer fishing season and thus distribute the catch and catch rate more evenly. The commercial landings of summer flounder have increased steadily since 1969, and the recreational catches have increased as well. The commercial landings of striped bass (Figure 4) have increased almost every year since 1958 (Jensen, unpublished data) and, judging from reports in the popular fishing literature, so have the recreational catches. There is no way at the present time to determine if the increases in landings for these species are the result of the size limits or in spite of them; however, the author suspects the latter. Anglers and commercial fishermen have stated in meetings with Department marine biologists that they see no need for changing the present size limits or of imposing catch limits. At the same time, the anglers advocate eliminating the commercial fishery for striped bass and restricting that for other species in New York waters in order to "protect" the fishes from "over-exploitation".

Because of the highly migratory nature of most of the fishes that enter both the commercial and recreational fisheries, it is unlikely that the State, unilaterally, could effectively manage any of them. Probably the relatively nonmigratory winter flounder and tautog are the only species that the State could attempt to manage. Thus, present State management is directed more toward the taker rather than the resource, with one notable exception. No license is required of resident commercial or recreational fishermen for taking saltwater finfish. However, licenses are required of non-resident operators of commercial fishing vessels for taking menhaden and foodfish.

Some State management efforts have been directed toward improving the opportunity for the anglers to gain access to the fish and toward improving their success in taking them. Launching ramps and fishing piers are prime examples of such access measures.

The State has constructed four boat launching ramps in the Marine

District for the small boat owner, but this is far less than is needed. About 140 launching ramps have been built by towns and villages on Long Island and by operators of fishing stations.[4] Unfortunately, the use of such ramps is often restricted to legal residents of the municipalities and to customers of the fishing stations. Others must pay a fee ($1.00 to $5.00) to launch their boats. Anglers have complained that such an arrangement discriminates against, and works a hardship on, persons from other areas or of limited income. There is no State program at this writing [1973] to provide for boat launching ramps.

Fishing piers, commercial and government-operated, are very successful in California and Florida (for example) and provide anglers many hours of recreation. In New York, some piers have been built in State parks (e.g., Captree State Park) and in some municipally-owned recreational areas. Cedar Beach in Mount Sinai in the Town of Brookhaven features one such pier. The State and the Town of Hempstead jointly constructed a fishing pier in Reynolds Channel at Point Lookout. The pier is used by many anglers who do not own boats or who do not, or cannot, rent boats or afford the $10 to $20 fare to fish aboard a head boat. This is particularly true for elderly and retired persons. Frequently, there are more anglers than the piers can comfortably accommodate and the resulting overcrowded conditions lessen the enjoyment many individuals look for in angling.

To increase the opportunities for fishermen in small boats to catch fish, the State has carried on a program of constructing artificial fishing reefs. The reefs are man-made structures of solid materials placed on the ocean bottom (or in a bay) to attract and concentrate fishes (Zawacki, 1969; Jensen, 1975b). The reefs include abandoned barges and ships, discarded concrete products and old automobile tires. They have been successful in providing excellent fishing for a variety of species wherever they have been built.

A major drawback to the construction of launching ramps, fishing piers and reefs is the great cost involved. In a review of the financial needs for a State program in marine fisheries (C. Zawacki, personal communication), the cost of an adequate ocean pier was found to be approximately $2.9 million, while an inshore pier (into Great South Bay or Long Island Sound) would cost $600,000 to one million dollars. The Mount Sinai fishing pier already mentioned (actually a boardwalk over an existing stone jetty) cost $149,000 in 1974. Fishing reefs also are expensive. A small reef (about 2.8 hectares) in Jamaica Bay was estimated to cost $18,000, assuming the materials were donated and that a non-union contractor did the work. A program to build reefs in

[4] According to "Public and Commercial Launching Ramps on Long Island", a leaflet published by the Nassau County Fish & Game Association, Inc.

the Atlantic Ocean would require nearly $40,000 per year for about 10 years.

Beach access sites are particularly expensive because they represent very desirable waterfront property. For example, 0.4 hectare of land on Long Island Sound, in 1975, was worth between $60,000 and $300,000. The necessary parking field, sanitary facilities and other improvements might cost an additional $100,000 per site. If the access site also included a boat launching ramp, this would add $300,000 to the total cost.

There is strong opposition to funding marine programs as elaborate as reefs, piers, launching ramps and access sites from the general revenues of the State. Opponents argue that it is unfair to make all the taxpayers of the State pay for facilities that provide amusement and recreation for a relatively few individuals, particularly if any number of them are non-residents of the State. It is better, the opponents say, to make the user pay for his recreation.

CONCLUSIONS

The data on commercial landings and effort, as measured by number of operators or gear fished, show a relatively straight-forward relationship. For example, the reported landings for red hake and silver hake show declines during periods when there were reductions in the numbers of otter trawls being fished. The decline in domestic landings, however, may also reflect a period of low abundance as the result of the massive foreign effort that began off the Long Island coast during the mid-1960's. In contrast, the landings of striped bass show a generally upward trend while the number of haul seines (the principal gear used to fish for that species) declined steadily over the past 25 years. The number of landings reported by the National Marine Fisheries Service as "hook and line" (mostly recreational anglers who sold their fish, according to F. Blossom of the Service, personal communication) increased as did the number of anglers.

The discussions in this paper are based on the assumption that it is desirable to manage our marine fisheries to provide the greatest good for the greatest number over the long run. Accepting this basic assumption, it must also be assumed that we shall try to manage these fisheries to secure the optimum sustainable yield, the definition of which, as used here, refers to the largest net economic return consistent with the biological capabilities of the stock, as determined on the basis of all relevant economic, biological and environmental factors. This is the definition set down by the US Senate Committee on Commerce on August 8, 1974. It seems desirable, however, to amend the definition by adding the social factor in determining the optimum sustained yield.

The environmental factors are basically two: natural and man-made.

There is little the fishery manager can do about the natural factors except to be aware of them and measure them for inclusion in his management model. Thus, the changing regional water temperatures can be expected to affect the biological factors, but there is nothing the manager can do about them. The man-caused environmental factors are under attack and have been for a long time. Most of them (particularly alterations to the marine environment e.g., dredging, filling, waste discharges, spills of toxic substances, etc.) are well covered in a substantial body of law. Enforcement of the existing laws will go a long way to at least ameliorate the impacts. As new environmental insults are encountered, they can be handled with existing or new legislation.

The biological factors are inherent in the organisms and, in our present state of knowledge, unchangeable by man. The biology of the organisms is directly linked to the environmental factors, particularly the natural ones. Here again, the manager's best attack is to study the organisms to develop the strongest and broadest data base for the management model to help describe and understand what is going on within the ecosystem.

The economic and social factors must be considered together. This is well illustrated by the striped bass controversy between commercial fishermen and recreational fishermen. Each faction argues that it makes the greater contribution to the local economy and, in its way, each is correct. The commercial fishermen require goods and services that are different from those that the anglers require. Similarly, each contributes goods and services that are different. It is clearly a case of comparing apples and oranges when one argues simplistically that either group contributes more or less to society than the other.

In the long run, the social factors will cause the fishery manager the greatest problem. They defy the scientific logic the manager has been taught and which he practices in his profession. Perhaps there is need for a new type of fishery manager, one who is trained in the social disciplines as well as in the fishery/biological disciplines. Perhaps there is need for a team approach, much like the physician-health sciences team that functions in dealing with human ills and how to alleviate them to maintain a healthy *corpus humanus*. Thus, we can envision a team of fishery biologists, economists and sociologists jointly participating in constructing a management model for specific fisheries.

Whatever the approach, it is going to cost money. Most users of natural resources, even non-consumptive users, are familiar with the need to pay for the privilege of their use. Visitors to National and State or local parks have become accustomed to paying entrance, parking and campsite fees. Hunters and freshwater fishermen have become accustomed to paying fees for licenses to enjoy their chosen outdoor activity. With only a few exceptions, the marine anglers of most states pay no fee

for the use they make of marine natural resources. But the time is fast approaching when a saltwater fishing license for anglers must be instituted to raise the revenues needed to construct fishing piers, artificial fishing reefs, boat launching ramps and other management measures. The monies also can be used to support very necessary management-oriented research to provide the data for the management models. Similarly, a revised and strengthened license fee structure for the State's commercial fishermen will make these users of the natural marine resources a partner in the management programs. Thus, user fees can serve to support new management programs to help the fishery manager to meet the demands caused by the social and environmental changes in the marine milieu.

A licensing system to include *all* harvesters of marine resources, most importantly, will provide much needed data for the resource manager. Patterned after the State licensing system now so successful with hunters and freshwater anglers, some measure could be made of the number of marine harvesters, the amount of their harvest, and the time and effort needed to take it. These basic data are sorely needed to insure wise, rational use of our fisheries resources.

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AN ECOSYSTEM CLASSIFICATION OF NEW YORK STATE FOR NATURAL RESOURCE MANAGEMENT[1]

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ABSTRACT

To facilitate environmental analysis and ecologically and socially sound decisions regarding the use of of natural resources, New York State is classified on the basis of its physiography into 13 primary ecosystems, eight of which are subdivided into 29 secondary ecosystems. Historical and contemporary interactions between land form and the total biota, including man, justify this linkage between the concepts of ecosystem and geomorphology. The term "ecosystem" is defined for practical application and is compared with several related classification systems. The advantages of a physiographic ecosystem concept as a basis for administration with respect to natural resources are discussed.

The evaluation of alternative uses of land is a matter of deep concern among thoughtful people. There must be a logical basis for setting policy and regulations affecting landuse, resource exploitation and conservation. The ideal basis should encourage the systematic inventory and analysis, of all natural resources, that are prerequisite for the planning that is a necessary foundation for maintaining a diverse and productive natural biota under present economic pressures.

There is a concensus that natural resources should be managed according to ecosystem principles (Van Dyne, 1969; Moen, 1973). However, little has been said about how ecosystems are distributed throughout a region or within the political subdivisions (e.g., states) that are the governmental units of society. The present paper outlines a basis for subdividing New York State into discrete regional ecosystems and describes how such a classification could serve practical management programs. It is largely a refinement of the work of Smith (1955) and Stout (1958) which foused on game animals and wood production, respectively, but were purely descriptive and did not suggest a functional purpose for the classifications presented. The paper also discusses the concept of ecosystem and its relationship to several other systems of biotic classification, but it does not attempt to define, scientifically, the "ecosystems" that may exist in New York. It only proposes a rationale for applying the term to physiographic regions, primarily for the purpose of better managing our

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total endowment of natural resources, assuming that these regions will subsequently be more fully analyzed as tenable ecosystems.

THE ECOSYSTEM CONCEPT

Although first used by Tansley (1935), the term ecosystem has come into wide use only within the past few years. Today many professionals, as well as laymen, use it without fully understanding its meaning or implications. Since the term is now an established part of our vocabulary, and is in fact an excellent short expression for a complex and real phenomenon, a working definition for it as it relates to management is needed.

Ecosystem has been defined by Odum (1971) as "any unit that includes all of the organisms (i.e., the "community") in a given area interacting with the physical environment so that a flow of energy leads to a . . . trophic structure, biotic diversity and material cycles". Thus used, it is a general term concerned with structural and functional relationships and is not related to any specific geographical area. In the broadest sense, excluding extraterrestrial realities, the planet Earth is The Ecosystem. Usually, though, the Earth's "living part" is called the biosphere, and this, in turn, is composed of various ecosystems.

In terms of Odum's definition, there is no standardized classification of the ecosystems of the Earth or its continents. The nearest approach is the biome classification (Clements and Shelford, 1939; Allee et al., 1949; Shelford, 1963) which subdivides North America into some seven to 12 regions based on "climax" vegetation (major plant formations of the botanical literature: see Oosting, 1958) and associated animal groups. Conceptually, the term is non-ecosystemic in that it disregards human influences and recognizes the abiota only by implication. Nonetheless, the wide acceptance of this scheme is evidenced by the fact that the American contribution to the International Biological Program followed the major biome types. New York State is located within the Temperate (Eastern) Deciduous Forest Biome, with Some Boreal Forest elements in the Adirondacks and high Catskills.

Odum (1971) further stated that "ecosystems may be conceived . . . in various sizes . . . as long as the major components are present and operate together to achieve some sort of functional stability". Ecosystems so identified are delimited arbitrarily and, therefore, the ecologist must strive to understand how any given one interacts with others. Within these guidelines, then, an ecosystem can be circumscribed anywhere depending upon the specific needs of the ecologist.

OTHER SYSTEMS OF BIOTIC CLASSIFICATION

There have been various attempts to subdivide the Earth and continents

according to regional differences in fauna and flora, e.g., zoogeographical realms (Sclater, 1858; Wallace, 1876; deBeaufort, 1951), faunal areas (Allen, 1892), life zones (Merriam et al., 1910), biotic provinces (Dice, 1943, 1952) and life areas (Aldrich, 1963, 1967). The biome system has been mentioned. Some of these authors were looking for fundamental truths that would explain the distinctive distributional patterns they observed, while others were simply describing such patterns. However, these classifications have various shortcomings. Basically, they are not fully integrated concepts, but tend to put too much emphasis on a few too variable factors. They can be regarded as classifications of certain ecological relationships, but they lack the holistic perspective required for an ecosystem. They are mentioned here because of their widespread appearance in the literature and because they could be misconstrued as already existing ecosystem classifications.[2]

THE PHYSIOGRAPHIC ECOSYSTEM

As has been noted, New York State is largely within the biotic region (biome) termed the Eastern Deciduous Forest. Although a useful description for broad interests, it does not account for the many distinctive biotic patterns that have developed in this region where the forest has been heavily modified by man's activities and that must be dealt with by biologists responsible for wildlife management. Subunits are needed, and physiographic features appear to afford the most practical means of differentiating them.

Basis For Physiographic Ecosystems

The major land formations of a region constitute its physiography or geomorphology (Lobeck, 1939). Land form is a reflection of the profound geologic events of the past which had a direct and indirect bearing upon both the development and extinction of biotas (Kendeigh, 1961; Udvardy, 1969). The type and structure of bedrock as exposed to uplifting, weathering and glaciation has had great influence on present topography and soils. In turn, the development of vegetation was (and is) to a great degree controlled by these factors (Braun, 1967), as well as by macro- and micro-climate and animals, including man. The native fauna that had evolved by the time western man arrived in New England was partially the result of adaptations to the natural vegetation (Shelford, 1963). Finally, the landuse activities of man have been greatly influenced by physiographic constraints (Thompson, 1966). Thus, geomorphology has a fundamental bearing on the physical and biological

[2]For a more comprehensive discussion of these earlier systems, see Kendeigh (1954, 1961) and Van Tyne and Berger (1959).

interactions that take place in an area. Therefore, boundaries of geomorphic (physiographic) provinces provide a logical basis for delimiting regional ecosystems. The physiography of New York is shown in Figure 1.

Practicality of Physiographic Ecosystems

A brief academic rationale for delineating ecosystems according to physiography has been presented. There are also several practical advantages to such a basis for classification. First, the physiographic characteristics of an area can be seen; they are prominent features of the landscape such as mountains, plateaus and valleys. In contrast, many other components of an ecosystem are "invisible". For example, who has ever actually seen an avifauna? Second, prominent land masses are relatively permanent compared with the more dynamic and variable biotic communities. And third, a physiographic basis for delineating ecosystems is considered appropriate because physiography has a major influence on human landuse and because man's activities are now the most important factors affecting the natural biota.

Problems Associated With the Physiographic Basis

Given the "spider web" complexity of ecological systems, any geographic defintion of them is arbitrary. The degree to which species or communities respect physiographic boundaries varies widely. Some are of relatively high resiliency and are little, if at all, constrained by physiography. The search for criteria that will neatly explain the distribution of plant and animal groups may prove as frustrating in the future as in the past.

Yet the distribution of individual species is often closely linked with a particular type of habitat which occurs only in certain physiographic provinces. Some wildlife species are associated with certain rock formations, e.g., cliff-nesting ravens in Virginia (Hooper et al., 1975) and golden eagles in the Adirondacks (Singer, 1974), and yellownose voles (*Microtus chrotorrhinus*) which are limited to rock outcrops and talus slopes at high elevations in Pennsylvania (Doutt et al., 1966) and New York. Wright and Wright (1949:5-6) presented a number of intriguing speculations regarding the relationship of anurans and geologic formations. Edgar A. Reilly (1975, personal communication) believes that the original range of the eastern massasauga (*Sistrurus catenatus*) in New York was confined to the lake plain in front of the retreating glacier and where there are now a few mucklands inhabited by this species.

The indirect effects of geomorphology upon biotic patterns are certainly of more importance to the composition of an ecosystem than the relatively specialized relationships that have been cited. For example, in New York, the geologically determined drainage and subsequent vegeta-

Figure 1. Physiography of New York State. (Map reproduced by permission of the Department of Geography at Syracuse University)

tion development and landuse in the western Adirondack hills have produced biotic associations distinctly different from those of the adjacent lake plains where another environmental complex prevails. Populations of the ringnecked pheasant (*Phasianus colchicus*) reside in the more intensively farmed lake plains, while wilderness species such as the black bear (*Ursus americanus*) occur in the more rugged, lightly developed Adirondack hills. These regions are not completely distinct, however, for there is biotic similarity and overlapping between them. Highly adaptive species, such as the white-tailed deer (*Odocoileus virginianus*), raccoon (*Procyon lotor*) and great horned owl (*Bubo virginianus*), can flourish anywhere in the State, although the ecology of a species may vary among regions. Nonresident migratory birds are another contributor to this diffusion.

One could attempt to divide New York into regions according to nonphysiographic criteria such as soils, vegetation and socio-economics or some combination of them. In fact this has been done for soils by Cline (1970), for vegetation by Bray (1930), DeLaubenfels (1966) and Ferguson and Mayer (1970) and for socio-economics by the Office of Planning Coordination (1971). Thompson (1966) integrated all of these factors in deriving regions. However, using such classifications for purposes of management with respect to the biota would be difficult if not unworkable. Soil and plant groups are either too general or too variable (depending on the nature of the classification) spatially, and the boundaries between types are often indistinct and hard to recognize. Human socio-economics are too dynamic to be used as a criterion for defining ecosystem boundaries, which should be based upon permanent features. The "composite uniform regions" of Thompson (1966) conform closely to the game range divisions described by Smith (1955) and the major physiographic provinces of New York. However, the author feels that these also are too general for purposes of intensive management with respect to the biota as a whole.

Any search for boundaries that will truly delimit specific ecosystems is fruitless because of the loosely integrated nature of the components of an ecosystem, particularly the biotic components. The biota consists of species (both as populations and as individuals) that are, to widely varying degrees, independent in behavior. This leads to a great variety of migrations, adjustments, exploitive "experiments", and competitive and chance encounters among organisms and their environment. Hence, any system with such individualistic elements defies rigid classification. The best that can be hoped for are units that satisfy an accepted definition, such as that of Odum (1971) as quoted earlier. For management purposes such units should have physical attributes which facilitate their easy recognition and be small enough to serve in dealing with local prob-

lems. The physiographic provinces described by Cressy (1966) fit these criteria well.

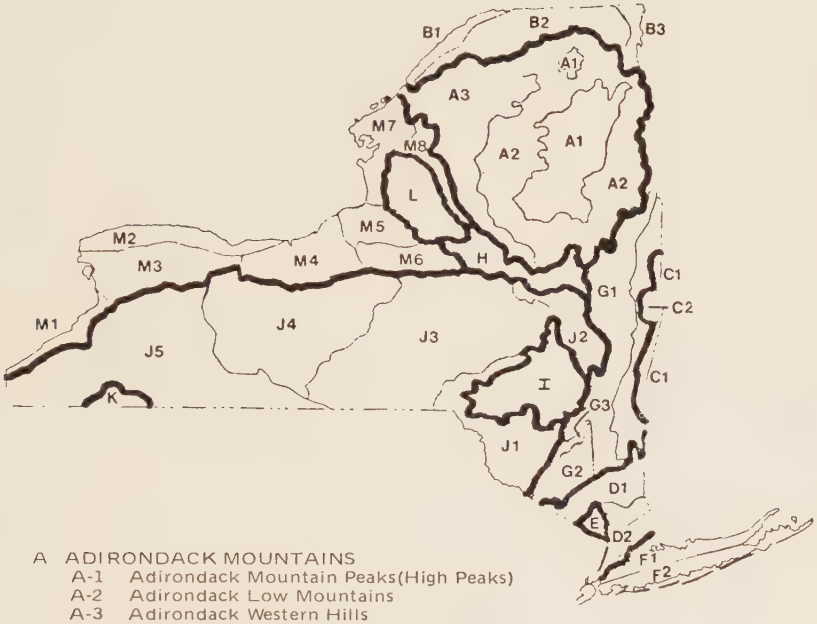
ECOSYSTEMS OF NEW YORK STATE

Thirteen primary ecosystems have been delineated in New York. Of these, the Tug Hill Upland, Mohawk Valley, Catskill Mountains, Triassic Lowland and Allegheny Hills are not subdivided, while the other eight are subdivided into 29 secondary ecosystems. Thus a total of 34 ecosystems are differentiated (Figure 2). This classification is based on the physiographic regions described by Cressy (1966), the only significant deviation being that four of his subregions are redesignated as primary regions (i.e., ecosystems). It is felt that these (i.e., Catskill Mountains, Allegheny Hills, Taconic Mountains and Hudson Highlands) are distinctive enough to justify the change. The present arrangement differs from the game range divisions described by Smith (1955) in recognizing secondary ecosystems and slightly different boundaries for several major regions.

Because resource management regulations often apply to areas that must be defined for purposes of law enforcement, if ecoystems are to be used as a basis for such regulations, their boundaries need to be established exactly. These boundaries could conform to drainage divides, major watercourses, highways and/or contour lines in closest proximity to the desired geomorphic parameter of the region. This precise delineation has not yet been done. Figure 3 shows the 34 ecosystems in relation to New York's political subdivisions.

The boundaries between physiographic ecosystems are often quite abrupt with respect to terrain. This is not true with ecological relationships as has been noted. The flow of energy and matter (including organisms) across arbitrary divides creates "ecotonal effects". It may be assumed that these effects are most pronounced where regions adjoin, and that the width of ecotones varies from perhaps a mile to several miles depending on the abruptness of change in the variables that influence it. In time, many ecotonal effects may be identified and interpreted by field ecologists.

For certain purposes drainage basins make good natural units for analyzing ecosystems, as in the Hubbard Brook research project (Borman and Likens, 1969). However, the broad management objectives considered here are not well served by a watershed basis at the regional level. New York's major watersheds lack the landscape of homogeneity possessed by the physiographic regions. Most of the 17 major watersheds (e.g., Hudson River, Mohawk River) include physiographic regions of distinctly different characteristics (e.g., the Adirondack High Peaks vs. the Taconic Mountains and the Mohawk Valley vs. the northern Catskill Mountains, respectively) thereby complicating management programs.



A ADIRONDACK MOUNTAINS
- A-1 Adirondack Mountain Peaks(High Peaks)
- A-2 Adirondack Low Mountains
- A-3 Adirondack Western Hills

B ST. LAWRENCE-CHAMPLAIN LOWLANDS
- B-1 St. Lawrence Marine Plain
- B-2 St. Lawrence Hills
- B-3 Champlain Lake Plain

C TACONIC MOUNTAINS
- C-1 Taconic Mountains
- C-2 Rensselaer Plateau

D HUDSON HILLS (SOUTHEAST HIGHLANDS)
- D-1 Southeastern Highlands
- D-2 Manhattan Hills

E TRIASSIC LOWLAND

F ATLANTIC COASTAL LOWLAND (COASTAL PLAIN)
- F-1 Harbor Hill-Ronkonkoma Moraines
- F-2 Long Island Outwash Plain

G HUDSON LOWLANDS
- G-1 Hudson Valley
- G-2 Wallkill Valley
- G-3 Shawangunk Mountains
- G-4 Taconic Foothills

H MOHAWK VALLEY

I CATSKILL MOUNTAINS

J APPALACHIAN UPLANDS (PLATEAU)
- J-1 Delaware Hills
- J-2 Helderberg Hills
- J-3 Susquehanna Hills
- J-4 Finger Lake Hills
- J-5 Cattaraugus Hills

K ALLEGHENY HILLS (MOUNTAINS)

L TUG HILL UPLAND (PLATEAU)

M ERIE-ONTARIO LOWLANDS
- M-1 Erie Lake Plain
- M-2 Ontario Lake Plain
- M-3 Southern Ontario Hills
- M-4 Ontario Drumlins
- M-5 Ontario Ridge and Swamplands
- M-6 Oneida Lake Plain
- M-7 Eastern Ontario Hills
- M-8 Black River Valley

Figure 2. Physiographic ecosystems differeniated in New York State.

Figure 3. Relationship of ecosystems recognized to political subdivisions (i.e., counties and towns) of New York State. (See Figure 2 for legend)

Within any of the physiographic ecosystems recognized (Figure 2) it might be desirable, for purposes of intensive management or analysis, to make further subdivision. At this level, watersheds or "edaphic climaxes", e.g., the Albany Pine Barrens (Bush) of the Hudson Valley region may then make ideal natural subunits.

ECOSYSTEMS IN RELATION TO WILDLIFE MANAGEMENT

Management based on regional differences in population ecology has been advocated for many years, as in the case of deer in New York (Cheatum and Severinghaus, 1950). However, this concern has been very largely for game species rather than toward the total vertebrate community. For example, the use of zones with different open seasons, harvest quotas and bag limits, based on the harvestable surplus or game availability, is an established practice with respect to deer and waterfowl hunting. Yet regulations for other game or furbearing species (e.g., squirrel, ruffed grouse, fox, muskrat) tend to be less related to zonal differences in population status. With regard to non-game animals, the immediate problem is not so much one of developing regional management policies and programs as it is one of justifying any substantial State involvement with this extensive segment of the fauna. Nevertheless, the ecosystem concept provides a framework for coordinated programs of research and management concerning the total biota within regions that have some ecological unity. By describing and understanding wildlife on a regional basis, decisions on management issues are put into a more realistic context. They more closely relate to species ecology as well as to the desires of the specific human populations who benefit from the local resource. Such a management concept is socially and ecologically sound, for as King (1966), paraphrasing Aldo Leoplod, said:

> "The objective of a wildlife conservation program is to retain for the average citizen the opportunity to see, hear, admire, enjoy and use and the challenge to understand the varied forms of wildlife living in his region. It implies not only that these forms be kept in existence, but that the greatest possible variety of them exist in each community. Wildlife management is . . . making land produce . . . wildlife in order that we (all the people) may realize the several values posessed by, and benefit from the many services performed by, this resources."

Once ecosystems have been delineated, the task becomes one of refining the description and understanding of them. Sound ecosystem management requires knowledge. Relatively detailed resource inventories are part of the process of developing this knowledge. Division of an area into regional ecosystems facilitates data collection and interpretation, and knowledge of regional differences improves management while the results of management programs add to such knowledge. In New York, for example, recent legislation (the Freshwater Wetlands Act) mandated a statewide inventory of all wetlands over 12.4 acres in size—a massive job.

SPECIES	ADIRONDACK MOUNTAINS	TUG HILL	ERIE-ONTARIO LAKE PLAIN	ST. LAWRENCE-CHAMPLAIN LOWLAND	APPALACHIAN PLATEAU	RENSSELAER PLATEAU TACONIC MTNS	HUDSON VALLEY	MOHAWK VALLEY	CATSKILL MOUNTAINS	SOUTHEAST (HUDSON) HIGHLAND	ATLANTIC COASTAL PLAIN	TRIASSIC LOWLAND MANHATTAN HILLS	PREFERRED HABITAT	Birth Site	Litters per Year	Home Range	Hibarnation-Migration
DIDELPHIDAE Opossum *(Didelphis virginiana)*	R	R	C	UNC	C	C	C	C	C	C	C	C	Mixed woodland & agricul. areas, part. lowlands	MO(p)	1	20-40a	WS,PR[W]
SORICIDAE Masked Shrew *(Sorex cinereus)*	C	C	C	C	C	C	C	C	C	C	C	C	Moist woodlands, hardwoods & softwoods, wetland thickets	GN(d)	3	¼a	A,PR
Smoky Shrew *(Sorex fumeus)*	C	C	UNC	UNC	C	C	C	C	C	C	R	UNC	Cool upl. deciduous & mixed woods, in A_0 horizon & old stumps, rock crevices	SC GN(d)	3		A,PR
Longtail Shrew *(Sorex dispar)*	UNC	-	-	-	R	-	-	-	UNC	-	-	-	Mountains, wooded rocky (talus) slopes, in litter & crevices	SC GN(d)	1		A,PR
Water Shrew *(Sorex palustris)*	C	C	-	-	UNC	R	-	-	C	R	-	-	Along swift or quiet streams w/densely vegetated (e.g.: alder) banks	SC	1-3		A,PR
Pigmy Shrew *(Microsorex hoyi)*	UNC	UNC	R	UNC	UNC	UNC	UNC	UNC	R	-	-	-	Woodland edges & upl. clearings, among forbs, tall grases & organic debri	SC GN(d)		¼a	A,PR
Least Shrew *(Cryptotis parva)*	-	-	R	-	UNC	-	UNC	R	R	UNC	R	R	Old fields, among grasses & forbs, also meadow & grain fields. Uplands, seldom in wet situations	GN(d)	4-5	1000 yd^2	A,PR
Shorttail Shrew *(Blarina brevicauda)*	C	C	C	C	C	C	C	C	C	C	C	C	Not restricted, all types of upl. woods part. w/A_0 horizon. Also old-fields & grasslands	SC GN(d)	2-3	½-2a	A,PR
TALPIDAE Eastern Mole *(Scalopus aquaticus)*	-	-	-	-	-	-	C	-	-	C	C	UNC	Rich woodland & grassland w/deep A_0 horizon, also sandy soils	SC	1	1-2a	A,PR
Hairytail Mole *(Parascalops breweri)*	C	C	UNC	C	C	C	C	C	C	C	-	C	Woodlands & open areas w/well-drained soil, sandy & organic	SC	1-2	1/5a	A,PR

Starnose Mole *(Condylura cristata)*	C	C	C	C	C	C	C	C	C	UNC	R	UNC	Low moist densely vegetated sites, incl. muck, adj. to streams & ponds	SC	1		A,PR
VESPERTILIONIDAE																	
Little Brown Myotis *(Myotis lucifugus)*	C	C	C	C	C	C	C	C	C	C	C	C	Roosts mainly in bldgs., forages over water, village shade trees. Open & wooded areas	B Mo(s)	1	1-2mi	WS,M
Keen's Myotis *(Myotis keenii)*	C	UNC	C	UNC	C	C	C	C	C	C	C	C	Woodlands near water. In mines, bldg., tree crevices.	TR(c) MO(s)	1		H, PR-M
Indiana Myotis *(Myotis sodalis)*	R	R	R	R	R	R	R	R	R	R	-	R	Known mainly from wintering caves. Does not favor bldgs.	MO(s)	1		H,M
Small-footed Myotis *(Myotis leibii)*	R	R	R	R	R	R	R	R	R	R	R	R	Occas. bldgs. & behind rock slabs. Cold dry caves & mines during winter. Near forests.	B, MO(s) TR(b)	1		H, M-PR
Silver-haired Bat *(Lasionycteris noctivagans)*	C	UNC	UNC	UNC	C	C	C	C	C	C	UNC	UNC	Woodlands, about ponds & streams. Winters in tree & rock crevices, bldgs.	MO(s)	1		H,M
Eastern Pipistrelle *(Pipistrellus subflavus)*	UNC	UNC	UNC	UNC	C	C	C	C	C	C	UNC	C	Wide-ranging, some pref. for woodlands near w ater. Winters in caves, mines, rock crevices.	MO(b)	1		H, M-PR
Red Bat *(Lasiurus borealis)*	UNC	UNC	UNC	UNC	C	C	C	C	C	C	UNC	UNC	Roosts in dense tree foliage, feeds about deciduous woods, in openings & wooded resid. areas, part. near water.	TR(f)	1	600-1000 yd.	H,M
Hoary Bat *(Lasiurus cinereus)*	UNC	UNC	R	R	UNC	UNC	UNC	UNC	UNC	UNC	R	R	Roosts in dense tree foliage. Deciduous & conif. woods, openings, old fields, wooded resid. areas, part. near water.	TR(f)	1		M
Seminole Bat *(Lasiurus seminolus)*	-	-	-	-	R	-	-	-	-	-	-	-	Southern species wanders north in summer. Habitat preferences prob. similar to other lasiurines.	TR(f)	1		M
Big Brown Bat *(Eptesicus fuscus)*	UNC	UNC	UNC	UNC	C	C	C	C	C	C	C	C	Favors bldgs. for roosting. Winters in caves & bldgs. Feeds about meadows, tree-lined streets.	B TR(b) MO(b,s)	1		H,M

Figure 4. Part of a list of New York mammals annotated with respect to relative occurrence in the primary ecosystems, preferred habitat and certain life history information. The ecosystems included differ from those in the legend in Figure 2 in that the Manhattan Hills and Triassic Lowland are combined as are also the Allegheny Hills and Appalachian Uplands. Notations are based on the best information available; however, data for many species are sparse thereby necessitating considerable speculation about status. (From unpublished manuscript "Preliminary Annotated List of the Wild Terrestrial Mammals of New York State" by J. A. Davis of the New York State Department of Public Service)

However, when each ecosystem is considered separately, data quickly become useful because each observation or measurement has a meaningful frame of reference. A summary of wetland types by size class according to regional ecosystems more readily facilitates value judgments about specific areas than does a more general tabulation.

Often a biologist needs to comment on the significance of the occurrence of a given species in a particular area. Structured inventories such as that shown in Figure 4 permit rapid checks of species status in a given ecosystem. From these data one may conclude, for example, that the discovery of a colony of water shrews (*Sorex palustris*) in good habitat in Orange County (Hudson Highlands) would be more remarkable than a similar finding in the Catskills. If this Highlands habitat were threatened by some human activity, the biologist, guided by the principle that faunal diversity has ecological merit, might recommend a change in developmental design to maintain the habitat of this beneficial and interesting predator. Where the animal is more common and widespread, extra expenditures for developmental modification might not be justified.

The value of using physiographic provinces as sampling strata in judging the magnitude of regional differences in statewide populations of breeding birds is demonstrated in the recent work of Brewster et al. (1976) in South Dakota and Stewart and Kantrud (1972) in North Dakota. In Pennsylvania, Ganis (1976) used a physiographic classification to derive a population estimate for the kestrel in the Great Valley section of that state.

Smith (1954), realizing the appropriateness of matching game research and management programs to regional conditions, prepared a fine historical description of New York State's physical environment, landuse and vegetation. This work never received wide circulation, being of value mainly as a reference for ecologically-oriented writers and biologists, although it was later published in shorter form (Smith, 1955). Apparently Smith, in his regional ecologic approach, was ahead of his time.

Today, "ecology" is a household word, and biologists are being asked to evaluate the impact of environmental change upon flora and fauna. Table 1 lists categories for which the compilation of original data, or data synthesis and interpretations, on a regional basis would contribute to such assessments. An integrated data bank, periodically updated, would permit the biologist to greatly improve his ability to provide desired information. All data (or analyses) should be readily retrievable and in a format that would facilitate interpretation.

Use of the ecosystem concept with respect to research and management programs would by no means solve all problems associated with encouraging high biotic diversity throughout the State. This paper has dealt mainly with the structure of ecosystems, saying little about their func-

Table 1. Some Ecosystem Components and Natural Resources For Which Inventory, Analysis and Interpretation on a Regional Basis Would Be Required For Management to Maintain Biotic Diversity and Sustained Yield

Abiota	Biota		
	Flora	Fauna	Mankind
Ecosystem components			
Climate Rock formations Surface deposits Land form Soils Drainage patterns Inorganic nutrients	Species present* Trees Shrubs and lianas Forbs and grasses Aquatics Ferns and club mosses Non-vascular forms†† Communities Distribution and extent Dominant species Diversity index Stand structure Dynamics	Species present* Mammals Birds Fish† Reptiles Amphibians Invertebrates††	Land use§ Agricultural Industrial Commercial Residential Mining Recreational
Natural Resources			
Air Water Minerals Soils (mineral) Building sites Scientific and cultural features	Wood and fiber Food crops Wildlife habitat Recreation and amenities Scientific values	Recreation and amenities Food Fur Scientific values	Culture Labor Enterpreneurs

* Distribution and relative abundance.
§ Past, present and future.
† Data would be analyzed on a watershed basis in relation to influencing physiographic regions.
†† Selected groups.

tional aspects, i.e., those which concern causes and effects and the "whys" of species occurrence and biotic structures. Attention to these functional relationships is also vital. But management concepts, in themselves, are of no value without the economic and attitudinal support of society. Sound ecosystem knowledge is only one of the many inputs needed for realizing the high goals expressed by such thinkers as Ralph King and Aldo Leopold.

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TOXICITY OF METHOXYCHLOR AND NALED TO SEVERAL LIFE STAGES OF LANDLOCKED ATLANTIC SALMON

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ABSTRACT

The toxicity of methoxychlor and naled was determined for several life stages of landlocked Atlantic salmon. By static bioassay, it was found that for methoxychlor the 24-hour LC_{50} to feeding fry and yearlings was 92 and 75 micrograms per liter, respectively. For naled, the 24-hour LC_{50} to feeding fry and fingerlings was 165 micrograms per liter. Effects other than death were also noted.

The New York State Department of Environmental Conservation is endeavoring to reestablish a sport fishery for landlocked Atlantic salmon (*Salmo salar sebago*) in the Lake Champlain drainage basin. Streams of the Bouquet, Salmon and Ausable River systems are being used as nursery streams for hatchery-reared fish stocked as feeding fry, fall fingerlings or yearlings. Until these fish become smolt during their first or second year, these nursery streams must support them.

Many streams of the New York portion of the Lake Champlain basin have been routinely treated with methoxychlor for control of the blackfly (Simulidae) since 1966. The part of the Bouquet River system within the Town of Elizabethtown was treated in 1973 and 1975, and the remainder was also treated in these years as well as in 1974. Portions of the Ausable River system were treated from 1972 through 1975. These treatments normally consist of three aerial applications of 15 per cent methoxychlor in a heavy aromatic naptha which is applied at the rate of 0.075 pound active per acre directly to streams in swaths 100 feet wide ¼ mile apart along the stream. Typically, these treatments are made in late April, early to mid May, and late May. They are timed to control the larvae of the species *Prosimulium hirtipes* and *Simulium venustrum* in the streams.

In addition, these areas are often subjected to up to three aerial applications of naled as Dibrom 14® as an adulticide space spray for mosquito and blackfly adults around populated areas. This material, an organophosphate, is applied at a rate of from 1 to 2 fluid ounces actual Dibrom concentrate per acre. This rate is equivalent to 0.1 to 0.2 pound active per acre. Although it is not applied directly to the water, some may reach the streams as runoff, drift and swamp drainage. The Bouquet watershed is usually treated with adulticide in late May or early June, mid-June and early July.

Thus, salmon yearlings in the nursery streams could be exposed to up to three treatments of each chemical. The stocked feeding fry may be exposed to one or two treatments of methoxychlor and to three treatments of naled. The number of exposures to methoxychlor would depend upon the stocking date which is in turn dependent upon the rate of development of the sac fry in the hatchery. It is important to know the toxicity of these insecticides to landlocked salmon in order to predict whether there is a chance that the treatments will kill fish.

The toxicity of naled to landlocked salmon is unknown. However, the U.S. Fish and Wildlife Service (1963) found an 18-hour LC_{50} of 80 ppb for 2- to 3-inch rainbow trout.

As part of their study on the effect of insecticides on the learning ability of Atlantic salmon, Hatfield and Johansen (1972) tested the toxicity of methoxychlor to salmon parr under unstated conditions. They found a 96-hour LC_{50} of 0.09 ppm. Katz (1961) found 24-, 48-, 72- and 96-hour TL_m values for methoxychlor using static bioassay procedures with coho salmon, chinook salmon and rainbow trout. For chinook salmon these values were 28.0 ppb for the 24-hour exposure and 27.9 ppb for the other three exposures. For coho salmon he found a TL_m value of 66.2 ppb for all four exposures. The TL_m values for rainbow trout were 62.6 ppb for all four exposure periods. Therefore, it appears that the toxicity of methoxychlor is manifested rather rapidly, and fish that survive the intial exposure will probably survive for at least 96 hours. If the methoxychlor in the test aquaria had broken down relatively rapidly, the fish that survived the initial exposure to high concentrations would have been exposed to lower concentrations as the experiment progressed. Merna and Eisele (1973) found that the rate of breakdown of methoxychlor varied with water productivity. The half life of methoxychlor ranged from more than 270 days in distilled water to 7 days in lake water with 60 miligrams per liter alkalinity and 80 milligrams per liter hardness. The authors conclude that in very unproductive waters long periods of exposure could result.

Since the Adirondacks are characterized by very unproductive waters, and a valuable sport fishery for landlocked salmon is being established, the effect of methoxychlor and naled was tested on landlocked salmon sac fry, feeding fry and yearlings, all of which would be in these streams during pesticide applications.

MATERIALS AND METHODS

Procedures used were those described by Doudoroff et al. (1951). The test animals were landlocked salmon sac fry, feeding fry, fingerlings and yearlings reared at the Adirondack Hatchery at Saranac Inn (N.Y.). The tests were run at the hatchery using the hatchery water supply from

Table 1. Characteristics of Water Used in Landlocked Salmon Bioassay at the Adirondack Hatchery

Life stage	Date	Water temperature (° C.)	Dissolved oxygen*	pH	Conductivity§
		Methoxychlor			
Yearling	April 1975	2	14.6	7.34	23
Sac fry	April 1975	2	14.6	7.34	23
Feeding fry	July 1975	20	8.2	6.72	34
		Naled			
Fingerling	August 1974	18	8.0	6.74	34
Feeding fry	July 1975	20	8.2	6.72	34

* Milligrams per liter.
§ Micromhos per centimeter.

Little Clear Pond. Water characteristics varied slightly between experiments and are summarized in Table 1.

Static bioassay procedures were used in this case because it was felt that they most closely approximate field conditions in which a stream or watershed receives one virtually simultaneous application of pesticide. Such breakdown of the pesticide as does occur would reduce its toxicity in the aquaria as it would in the field.

Methoxychlor, a chlorinated hydrocarbon, was tested on three stages of salmon: fry, feeding fry and yearlings. The methoxychlor used was a 15 per cent by weight formulation (specific gravity 0.952) consisting of 15 parts of technical grade methoxychlor, 84 parts heavy aromatic naptha and 1 part Triton X185® emulsifier. These chemicals were obtained from Duflo Spray Chemical Co., the applicator that regularly treats Adirondack streams under contract to local governments. A stock solution of 1,000 milligrams active per liter was made by placing 0.70 milliliter of 15 per cent spray mix in a 100-milliliter volumetric flask and filling the flask with acetone.

The toxicity of naled, an organophosphate insecticide, was tested on salmon feeding fry and fingerlings. The naled used was the Dibrom 14® concentrate formulation manufactured by Chevron Chemical Corporation. This material is 85 per cent active by weight with a specific gravity of 1.83. A stock solution of 1,835.5 milligrams active per liter was made by placing 0.118 milliliter of Dibrom 14 in a 100-milliliter volumetric flask and filling the flask with acetone.

Test aquaria were 20-liter round glass jars. These were placed in flowing water of relatively constant temperature in hatchery troughs. In all cases simultaneous control aquaria were used. All fish were unfed for at least 2 days prior to the test and were held in the same water as used in the test and at the same temperature. The duration of all tests was

24 hours because this is probably the longest duration of exposure in the stream.

During tests run in the summer of 1974 and the spring of 1975, acetone was added to the control aquaria in the same concentrations as the highest test concentration. Control fish were unaffected by the acetone. Based on this and previous work, no acetone was added to the control aquaria in the summer of 1975.

TOXICITY OF METHOXYCHLOR

To test the toxicity of methoxychlor to sac fry, 20 sac fry were put in 16 liters of water for each concentration tested. The average lengh of these fish was 25 millimeters. Water temperature was maintained at 2° C., and dissolved oxygen remained over 13 milligrams per liter. At concentrations of up to 2.4 milligrams active methoxychlor per liter, no sac fry died. No higher concentrations were tested because they would be much higher than any possible stream concentration after treatment. However, fish exposed to much less of the methoxychlor were obviously affected. At 0.56 milligram per liter, sac fry behavior was characterized by slow movement and little response to stimuli in the jar. As the concentrations

TABLE 2. EXPERIMENTAL CONDITIONS AND RESULTS FOR BIOASSAY OF METHOXYCHLOR ON LANDLOCKED SALMON FEEDING FRY, JULY 1975

Concentration*		Number of fish	Dissolved oxygen§		Water temperature (° C.)	Mortality after 24 hours	
			At start	After 24 hours		Number	per cent
Control	Jar 1	10	8.7	6.0	19.0-20.0	0	0
	Jar 2	10	8.4	4.4			
42	Jar 1	10	8.4	6.1	19.0-19.5	0	0
	Jar 2	10	8.4	5.9			
56	Jar 1	10	8.4	4.7	19.0	0	0
	Jar 2	10	8.4	4.9			
75	Jar 1	10	8.4	4.7	19.0-19.5	2	10
	Jar 2	10	8.4	5.7			
87	Jar 1	10	8.7	3.6	19.0-19.5	0	0
	Jar 2	10	8.7	3.6			
100	Jar 1	10	8.7	4.7	19.0-19.5	16	80
	Jar 2	10	8.4	5.7			
135	Jar 1	10	8.7	6.6	19.0	20	100
	Jar 2	10	8.7	6.3			
155	Jar 1	10	8.7	7.1	18.5-19.0	20	100
	Jar 2	10	8.7	7.0			

* Micrograms per liter.
§ Milligrams per liter.

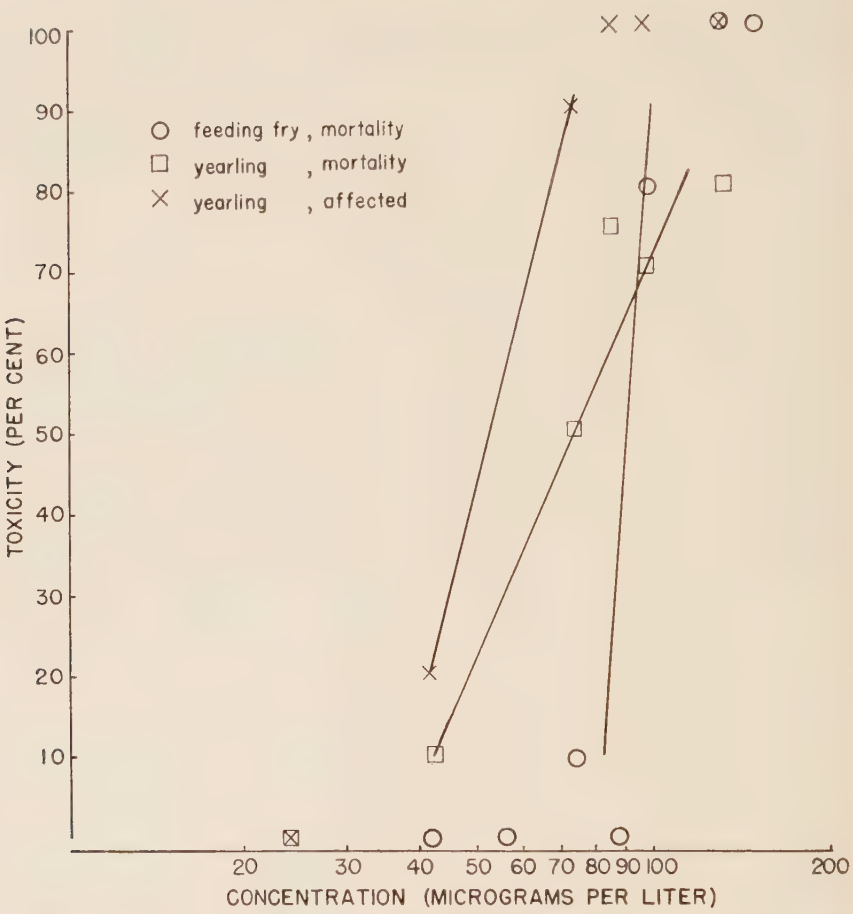

Figure 1. Toxicity (in terms of percentage of fish that died or that were affected) of methoxychlor to feeding fry and yearling landlocked salmon.

were increased, this hyporeactivity apparently increased, but death did not occur in any case.

Since sac fry and feeding fry may exhibit different susceptibility to toxicants, further tests were conducted after the salmon began feeding. These tests were run in mid-July of 1975 using fry which had been feeding for approximately a month. The salmon used ranged from 39 to 53 millimeters long with a mean length of 45 millimeters. Water characteristics at the time of the test are listed in Table 1. Tweny fish were exposed for 24 hours to each of eight logarithmic concentrations including a control. For each concentration, 10 fish were exposed in each of two jars containing 10 liters of dilution water. No control fish died or appeared to be affected. The data from this test are listed in Table 2. These

Table 3. Experimental Conditions and Results For Bioassay of Methoxychlor on Landlocked Salmon Yearlings, April 1975

Concentration*	Number of fish	Dissolved oxygen§		Water temperature (° C.)	Mortality after 24 hours		Toal affected after 24 hours	
		At start	After 24 hours		Number	Per cent	Number	Per cent
Control	9	13.7-13.9	11.2-13.8	2	0	0	0	0
24	10	13.9	10.5-12.8	2	0	0	0	0
42	20	13.7-13.9	10.9-12.6	2	2	10	4	20
75	20	13.7-13.9	8.8-11.7	2	10	50	18	90
87	20	13.7-13.8	8.6-11.5	2	15	75	20	100
100	10	13.8	9.9-11.4	2	7	70	10	100
135	10	13.8	9.8-11.7	2	8	80	10	100

* Micrograms per liter.
§ Milligrams per liter.

data were plotted on semi-logarithmic paper with the concentrations on the logarithmic axis (Figure 1). The 24-hour LC_{50} was determined graphically to be 92 micrograms per liter.

Methoxychlor was also tested on landlocked salmon yearlings in the same water in April of 1975. In this test 16 liters of dilution water were used in each jar. The fish ranged from 74 to 120 millimeters in length with a mean of 98 millimeters. Due to their size, only three or four were placed in each jar. They were exposed for 24 hours to seven concentrations including a control. The results are tabulated in Table 3, and the data are plotted in Figure 1 in the same manner as those for the sac fry and feeding fry. The 24-hour LC_{50} was determined graphically to be 75 micrograms per liter. No control fish died or seemed affected in any way.

At concentrations of 42 micrograms per liter and over, some fish were not killed but did seem to be severely affected. These fish either rolled over at the top of the jar or rested on their side at the bottom. They showed little response to external stimuli. The number affected at each concentration was determined by adding the number of such individuals to the number that died. These results are also listed in Table 3. When the percentage affected was plotted over the logarithmic concentration as shown in Figure 1, an EC_{50} of 54 micrograms per liter was deter-

Table 4. Experimental Conditions and Results For Bioassay of Naled on Landlocked Salmon Feeding Fry, July 1975

Concentration*		Number of fish	Dissolved oxygen§		Water temperature (° C.)	Mortality after 24 hours	
			At start	After 24 hours		Number	Per cent
Control	Jar 1	10	8.7	6.0	19.0-20.0	0	0
	Jar 2	10	8.4	4.4			
77	Jar 1	10	8.4	6.2	19.0-19.5	0	0
	Jar 2	10	8.4	5.9			
103	Jar 1	10	8.4	5.4	19.0-19.5	0	0
	Jar 2	10	8.4	5.2			
138	Jar 1	10	8.4	5.5	19.0-19.5	0	0
	Jar 2	10	8.4	5.3			
160	Jar 1	10	8.7	4.8	19.5-20.0	12	60
	Jar 2	10	8.7	4.5			
184	Jar 1	10	8.7	5.2	19.0-19.5	16	80
	Jar 2	10	8.4	5.1			
211	Jar 1	10	8.7	5.8	19.0-19.5	20	100
	Jar 2	10	8.7	5.5			
285	Jar 1	10	8.7	7.0	19.0-19.5	20	100
	Jar 2	10	8.7	7.0			

* Micrograms per liter.
§ Milligrams per liter.

mined. The fish which were alive but obviously affected at the end of 24 hours were put into uncontaminated water. All died within 48 hours.

TOXICITY OF NALED

The toxicity of naled to landlocked salmon feeding fry was determined in July of 1975 using fish that had been feeding for about a month. These fish ranged from 38 to 53 millimeters in length with a mean of 45 millimeters. Twenty fish were tested at each of eight concentrations including a control. Each jar held 10 liters of dilution water, and 10 fish were tested in each jar. A 24-hour static bioassay procedure was used. The results are tabulated in Table 4. The percentage mortality was plotted over the logarithm of the concentration (Figure 2), and an LC_{50} of 165 micrograms per liter was determined graphically. The steep slope of this line indicates that an extremely small increase in toxicant in the critical concentration range will produce very high mortality.

Naled was also tested on salmon fingerlings at the end of their first

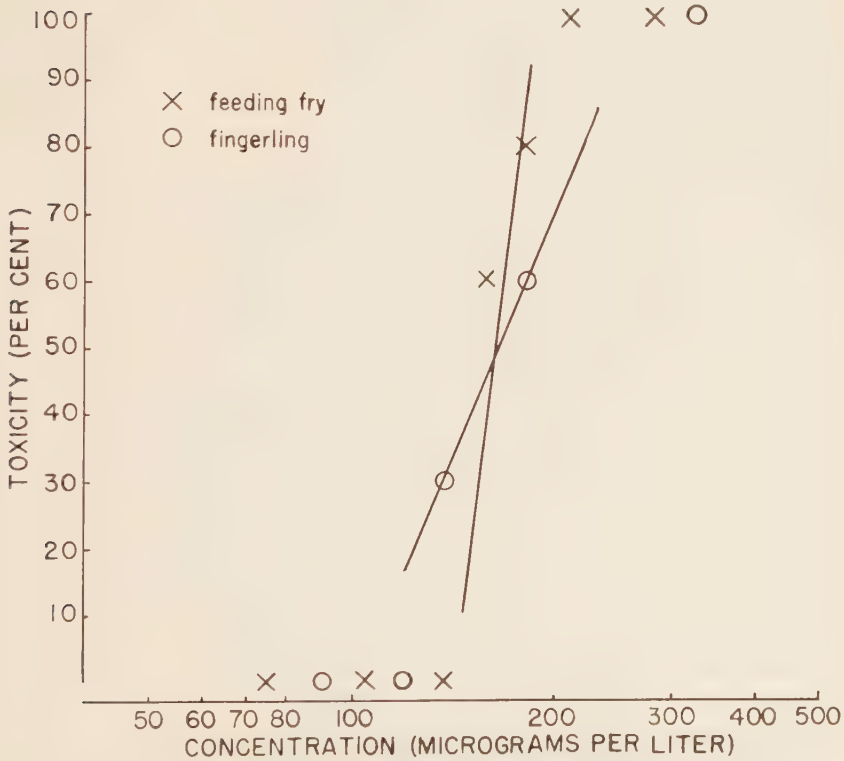

Figure 2. Toxicity (in terms of percentage of fish that died) of naled to feeding fry and fingerling landlocked salmon.

Table 5. Experimental Conditions and Results For Bioassay of Naled on Landlocked Salmon Fingerlings, August 1974

Concentration*	Number of fish	Dissolved oxygen§		Water temperature (° C.)	Mortality after 24 hours	
		At start	After 24 hours		Number	Per cent
Control	6	7.6	5.4-4.5	18.5-20.0	0	0
Control	4	8.4	6.2	16.0	0	0
90	10	7.6	4.9-5.4	18.5-20.0	0	0
119	10	7.6	4.3-5.2	18.5-20.0	0	0
138	10	8.4	4.2-5.5	19.0	3	30
184	10	8.4	4.6-4.8	19.0	6	60
330	10	8.1	6.7-7.2	16.0	10	100

* Micrograms per liter.
§ Milligrams per liter.

summer in 1974. These fish ranged from 55 to 75 millimeters in length with a mean of 64 millimeters. Six concentrations were tested including a control. The fish were held in jars containing 12 liters of hatchery water during the test. In order that the oxygen would not be depleted, only three or four fish were tested in each jar. The results are summarized in Table 5. The percentage mortality was plotted over the logarithm of the concentration (Figure 2), and an LC_{50} of 165 micrograms per liter was determined graphically.

CONCLUSIONS

These tests indicate that the 24-hour LC_{50} of methoxychlor to landlocked salmon feeding fry and yearlings is 92 and 75 micrograms per liter, respectively, and that the 24-hour EC_{50} to salmon yearlings is 54 micrograms per liter. The 24-hour LC_{50} of naled to feeding fry and fingerlings is 165 micrograms per liter.

Under usual pesticide-application procedures, the concentration of methoxychlor in a stream 0.3 meter deep would theoretically be 28 micrograms per liter. At an application rate of 1.5 fluid onces of Dibrom 14 per acre, the corresponding concentration would be 54 micrograms per liter. Reduced water depth would proportionally increase these theoretical concentrations. It is highly unlikely that fish in these Adirondack nursery streams would ever experience a full 24-hour exposure to either of these chemicals.

Thus, it appears that under the usual conditions of pesticide application no landlocked salmon mortality is likely to occur. However, the theoretical exposure of these fish to methoxychlor and naled is high enough that the likely short exposure time provides the only real margin of safety. Therefore, more study on the sub-lethal and long-term effects of these chemicals is needed.

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STATUS OF TAUTOG POPULATIONS AT ARTIFICIAL REEFS IN NEW YORK WATERS AND EFFECT OF FISHING[1]

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ABSTRACT

Population estimates indicate that as many as 18,898 tautog were attracted to the Kismet artificial reef in Great South Bay. There, the fish averaged only 216 millimeters long, while at the Fire Island artificial reef in the Atlantic Ocean they averaged 280 millimeters. Tag returns indicate that a migration of tautog from Kismet reef began in October each year and that these fish overwintered in the inshore waters of the northwestern corner of the New York Bight. Data for mortality, growth rate and age at sexual maturity indicate that the population studied is not achieving its potential productivity. Assuming this population to be representative of that in New York waters generally, in order that females spawn at least once it would be necessary to raise the minimum size of tautog that may be taken to 9 inches (228 millimeters) and apply this size limit to both the sport and commercial fisheries.

The tautog (*Tautoga onitis*) is one of the more important sport fish in Long Island waters (Briggs, 1962, 1969). These fish favor rough, rocky bottoms and are attracted to artificial reefs (Briggs, 1975; Zawacki, 1969). Size composition, population numbers, movement and survival of

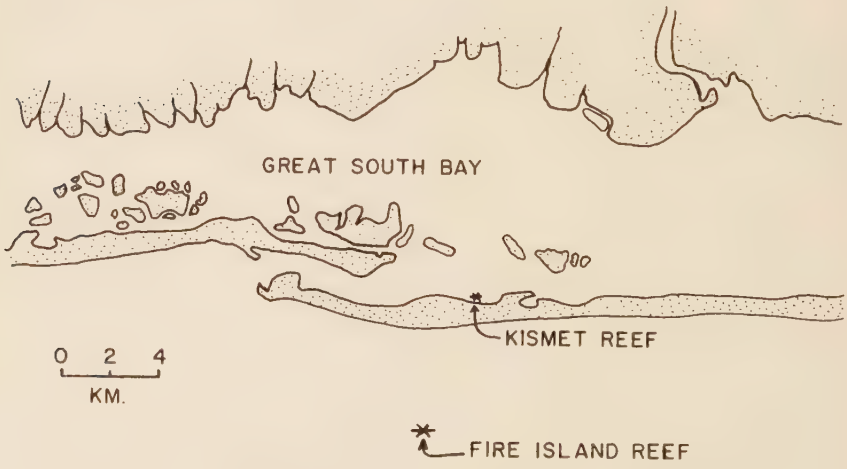

Figure 1. Map showing location of the reefs.

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tautog were studied at two artificial reefs in New York waters from 1969 to 1972. Kismet reef lies in approximately 6 meters of water in Great South Bay (Figure 1). It is 457 meters long and 46 meters wide. Fire Island reef lies in approximately 21 meters of water in the Atlantic Ocean about 4 kilometers south of the barrier beach. It is 1.6 kilometers long and 0.2 kilometer wide. These reefs were described in detail by Briggs (1975).

METHODS

Tautog were caught in fish pots set at the reefs from May through November in 1969, 1970 and 1972 and from May through July and late September through early December in 1971. Briggs (1975) described the pots and the method of fishing them. All tautog caught were measured to the nearest 5 millimeters in total length. All those greater than 120 millimeters long in 1969 and all those greater than 150 millimeters long in 1970, 1971 and 1972 were tagged with either Floy® anchor tags or Petersen discs. The numbers of fish tagged each year with each type of tag are given in Table 1.

Enough tagged tautog were recaptured in the sampling gear at Kismet reef to allow population estimates to be made by the Schnabel method (Ricker, 1958). These estimates were calculated in 1969, 1970 and 1972 for the period during the summer and early fall before heavy fishing pressure made the results untenable, and 95 per cent confidence limits were calculated using the method described by Ricker (1958). No population estimates were made in 1971 because equipment failure forced a halt in sampling from the end of July through late September.

Extensive promotion and advertisement were undertaken to recover tags. Posters were distributed and placed in bait shops and aboard party boats. News releases were published in local and New York City news-

TABLE 1. NUMBERS OF TAUTOG TAGGED AT ARTIFICIAL REEFS

Year	Anchor tag	Petersen disc	Total
Kismet reef			
1969	860	676	1,536
1970	721	719	1,440
1971	463	595	1,058
1972	1,152	0	1,152
Total	3,200	1,986	5,186
Fire Island reef			
1969	18	27	45
1970	76	61	137
1971	30	6	36
1972	41	0	41
Total	165	94	259

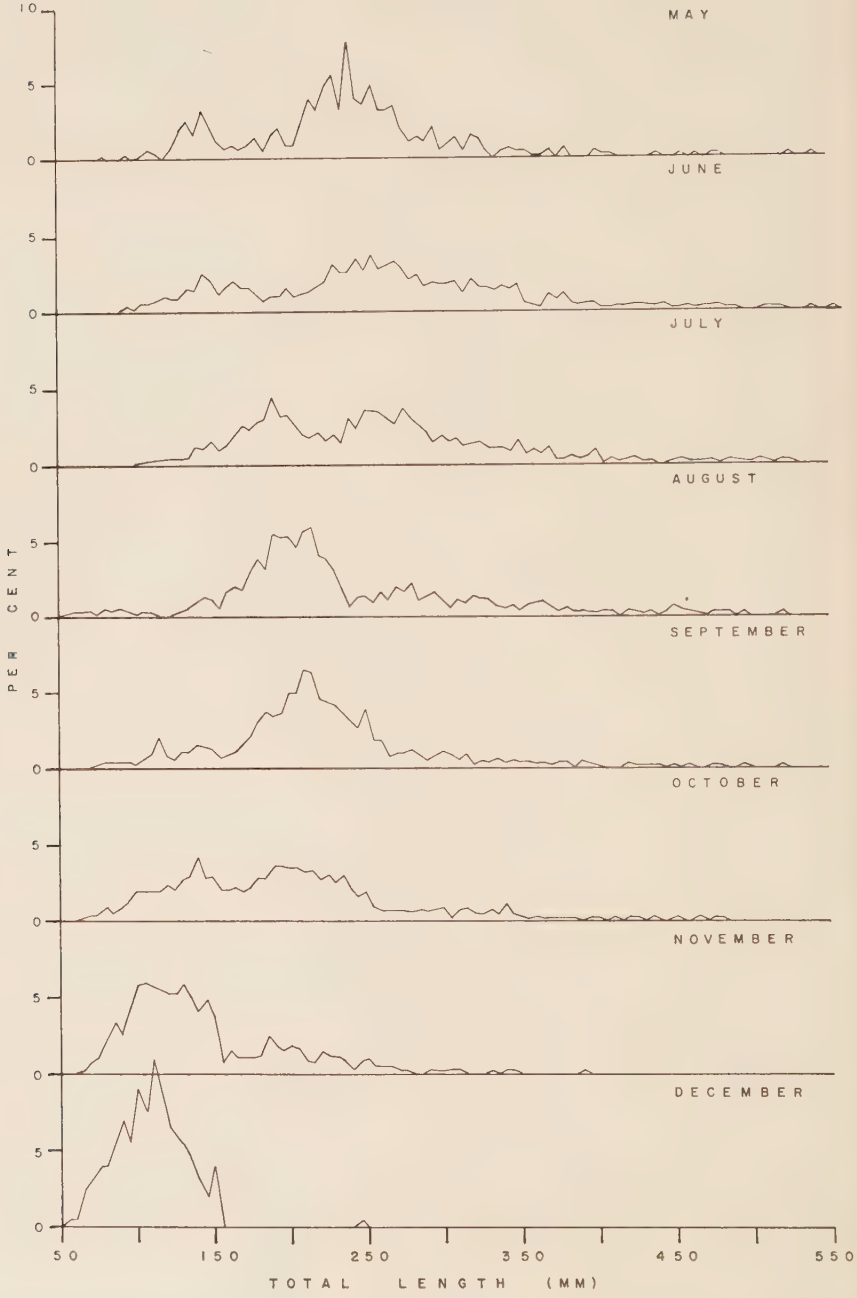

Figure 2. Length-frequency distribution (in per cent), by month, for tautog caught at Kismet reef.

Table 2. Size of Tautog Caught At Artificial Reefs For All Years Combined

Item	Total length* by month								
	May	June	July	August	September	October	November	December	
Kismet reef									
Range	75-540	95-555	110-525	60-520	75-520	65-480	40-390	35-245	35-555
Mean	238	257	252	234	218	194	142	108	216
Number	433	1,095	1,170	626	1,134	1,487	730	200	6,875
Fire Island reef									
Range	180-340	165-380	165-400	175-420	120-525	125-495	165-520	150-190	120-525
Mean	244	249	257	265	273	275	326	170	280
Number	7	18	13	23	22	158	55	2	298

* In millimeters.

papers and were broadcast over local and metropolitan radio stations. The author explained the program in talks at sportsmen's organizations. A one dollar reward and information pertinent to the recovered fish were offered to encourage tag returns.

Estimates of survival, total mortality, fishing mortality and natural mortality were made according to the methods outlined by Ricker (1958).

RESULTS

Data derived from the tag returns provide information on the status and dynamics of the tautog populations at the two artificial reefs, especially Kismet reef, which may be representative of the tautog population in New York waters generally.

Size Composition

Graphs of the length-frequency distribution of tautog caught at Kismet reef (Figure 2) show a relatively stable population, with all sizes represented, until the fall. Small fish (less than 200 millimeters long) dominated the catches there in the fall. By December, almost no tautog over 150 millimeters long were being caught at this site.

Because of the small numbers caught at Fire Island reef in the spring and summer, graphs of the length-frequency distribution of the tautog there were prepared only for October and November (Figure 3). These

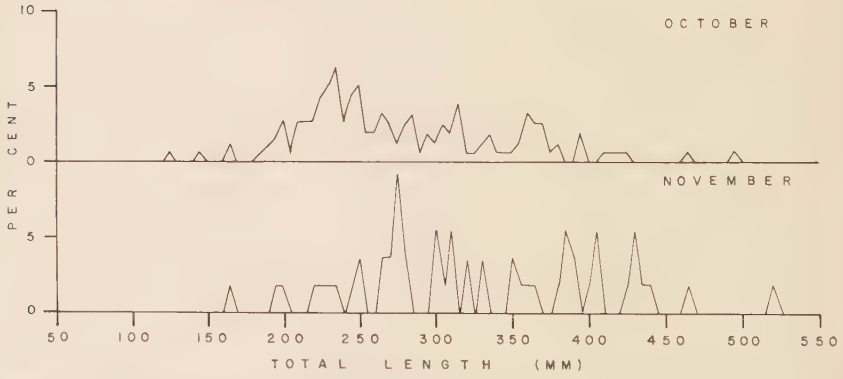

Figure 3. Length-frequency distribution (in per cent) for tautog caught at Fire Island reef during October and November.

graphs show a near absence of tautog less than 200 millimeters long in the fall.

Tautog averaged 275 and 326 millimeters long at Fire Island reef in October and November, respectively, but at Kismet reef the corersponding measurements were only 194 and 142 millimeters (Table 2). For the

entire season (May to December), tautog averaged 280 millimeters long at Fire Island reef and 216 milimeters at Kismet reef.

SIZE AT MATURITY

Cooper (1966) stated that both sexes become mature at 3 years of age. The length distribution of running ripe tautog taken by project personnel is shown in Table 3. Males were first found to be ripe at 215 millimeters which is within the range of back-calculated lengths at age III for fish

TABLE 3. LENGTH FREQUENCIES OF RUNNING RIPE TAUTOG CAUGHT IN POTS AT ARTIFICIAL REEFS

Total length* (millimeters)	Number	
	Male	Female
215	1	..
220	..	..
225	1	..
230	1	2
235	..	..
240	2	..
245	..	..
250	2	..
255	1	..
260	..	1
265	1	1
270	1	..
275	1	2
280	..	..
285	4	..
290	1	1
295	3	..
300	2	..
305	2	..
310	..	..
315	1	1
320	1	1
325	1	..
330	3	..
335	..	..
340	2	..
345	..	..
350	1	1
355	..	..
360	..	..
365	..	..
370	1	..
375	..	..
380	1	..
385	1	..
390	1	..
395	..	..
400	..	..
410	1	..
430	2	..
440	1	..
475	1	..

* Lengths were recorded to nearest 5 millimeters: above 400 millimeters, only categories in which specimens occurred are listed.

Table 4. Estimates of Tautog Population At Kismet Reef During the Summer and Early Fall in 1969, 1970 and 1972

Date	Population estimate*	Confidence limits (95 per cent)
1969		
July 8	5,615	2,825 - 500,000
10	6,008	3,205 - 50,000
14	7,186	3,831 - 58,824
16	9,195	4,854 - 83,333
18	10,455	5,556 - 90,909
22	13,127	6,993 - 111,111
23	16,283	9,390 - 61,350
25	15,253	8,734 - 59,880
28	12,006	7,843 - 30,769
29	15,081	9,477 - 36,900
30	15,727	10,030 - 36,364
August 4	14,799	9,588 - 32,362
5	13,357	8,865 - 27,027
8	13,142	8,898 - 25,126
12	13,993	9,488 - 26,596
15	13,594	9,372 - 24,691
18	14,674	10,132 - 26,667
19	15,334	10,570 - 27,933
21	15,774	10,965 - 28,090
25	18,521	12,870 - 33,003
29	18,081	12,755 - 31,506
September 3	18,322	13,643 - 31,348
5	16,737	12,107 - 27,174
10	18,015	13,004 - 29,326
15	18,542	13,532 - 29,498
17	18,341	13,567 - 28,305
18	17,497	13,096 - 26,357
1970		
May 26	2,108	1,059 - 212,766
June 2	3,238	1,626 - 400,000
3	2,385	1,364 - 9,479
8	2,096	1,321 - 5,339
10	2,158	1,413 - 4,560
15	2,656	1,761 - 5,405
17	2,668	1,788 - 5,258
19	3,146	2,108 - 6,203
23	3,542	2,373 - 6,983
25	3,821	2,610 - 7,133
30	3,795	2,614 - 6,920
July 2	3,973	2,737 - 7,264
8	4,136	2,848 - 7,547
10	4,198	2,890 - 7,669
14	4,344	2,992 - 7,924
16	4,321	3,044 - 7,446
20	4,537	3,195 - 7,825
21	4,667	3,297 - 7,981
24	4,887	3,466 - 8,285
28	5,016	3,577 - 8,389
30	5,224	3,747 - 8,628
August 4	5,568	4,000 - 9,158
7	5,581	4,052 - 8,961
11	5,159	3,848 - 7,831
14	5,276	3,949 - 7,949
18	5,345	4,000 - 8,052
20	5,711	4,264 - 8,643
24	6,175	4,655 - 9,174

TABLE 4. (*continued*)

Date	Population estimate*	Confidence limits (95 per cent)
27	6,540	4,929 - 9,718
28	6,509	4,926 - 9,597
September 1	7,021	5,328 - 10,299
4	7,627	5,787 - 11,186
9	7,986	6,112 - 11,521
11	8,492	6,506 - 12,270
18	9,073	6,949 - 13,071
	1972	
June 20	2,608	1,310 - 256,410
21	3,993	2,007 - 400,000
23	3,293	1,852 - 12,870
27	3,941	2,259 - 15,432
29	4,582	2,627 - 17,953
July 11	5,924	3,282 - 22,371
12	6,303	3,716 - 20,790
17	8,706	5,133 - 28,736
19	9,027	5,663 - 22,222
20	10,414	6,504 - 25,575
25	13,322	8,489 - 30,864
August 14	14,696	9,390 - 33,670
15	14,559	9,443 - 31,746
17	15,887	10,428 - 33,223
23	15,739	10,460 - 31,847
29	16,680	11,062 - 33,784
September 6	16,466	11,173 - 31,348
12	17,815	12,077 - 34,014
14	18,898	12,920 - 35,211

* Fish greater than 120 millimeters in total length in 1969, and greater than 150 millimeters in 1970 and 1972.

from Rhode Island waters as given by Cooper (1967). The smallest ripe females were 230 millimeters long which is within the range for age IV as given by Cooper. It seems that females may reach maturity later in the more southerly waters of New York than in Rhode Island waters.

POPULATION ESTIMATES

Population estimates for tautog at Kismet reef, derived by the Schnabel method, are shown in Table 4. The best estimates (i.e., according to this method, the last of the series in each case) of the tautog population before the onset of heavy fishing pressure each year were 17,497 fish over 120 millimeters long in 1969, and 9,073 and 18,898 over 150 millimeters long in 1970 and 1972, respectively.

MOVEMENT

The locations of the returns for tautog tagged at Kismet reef are summarized in Table 5 and Figure 4. Most of the returns were from the tagging site in September and October. That the preponderance occurred

TABLE 5. SPECIFIC LOCATIONS FOR RECAPTURES OF TAUTOG TAGGED AT KISMET REEF*

Month	Location	Number	Remarks
January-March	..	0	
April	Ambrose Light buoy	1	New York Bight
May	Kismet reef	5	
	Fire Island Inlet	2	
	Great South Bay	1	
	South Oyster Bay	1	
	Stone Ridge off Point Lookout	1	New York Bight
	Rockaway Beach	1	New York Bight jetties
	Manasquan (N.J.).	1	New York Bight
June	Kismet reef	8	
	Fire Island Inlet	5	
	Great South Bay	1	
	South Oyster Bay	1	
	"T" wreck	1	New York Bight, at Jones Inlet
	unknown	1	
July	Kismet reef	1	
	Montauk	1	Fort Pond Bay
	Shinnecock Inlet	1	
August	Kismet reef	2	
	Fire Island Inlet	1	
	Moriches Bay	1	
	"T" wreck	1	
September	Kismet reef	97	
	Fire Island Inlet	5	
	Great South Bay	3	
	South Oyster Bay	2	
	Shinnecock Inlet	1	
	Ambrose Light buoy	1	
October	Kismet reef	325	
	Fire Island Inlet	16	
	Great South Bay	3	
	South Oyster Bay	1	
	Fire Island	1	New York Bight, off Fair Haven
	Drumelzia wreck	1	New York Bight, east of Fire Island
	Off Fire Island Inlet	1	New York Bight, 1.2 kilometers south of inlet
	Rota wreck	1	New York Bight, off Tobay Beach
	"T" wreck	1	
	Jones Inlet	1	
	Hempstead Town reef	1	New York Bight, west of Jones Inlet
	Iberia wreck	2	New York Bight, off Long Beach (N.Y.)
	Atlantic Beach reef	2	New York Bight

TABLE 5. (*continued*)

Month	Location	Number	Remarks
	Rockaway Beach	1	Jetty
	Wrecks off Rockaway Beach	3	New York Bight
	Cholera Banks	1	New York Bight
	unknown	1	
November	Kismet reef	10	
	Fire Island Inlet	4	
	Great South Bay	1	
	Wreck off Jones Beach	1	New York Bight, 16.8 meters of water
	Atlantic Beach reef	2	
	Cholera Banks	1	
	Off Long Beach (N.J.)	1	New York Bight
December	Cholera Banks	1	
No date	Kismet reef	2	

* Exclusive of those caught in project gear.

Figure 4. Map showing locations of recaptures of tautog tagged at Kismet reef. Two additional recoveries were made at unknown locations.

in the fall is indicative of the heavy fishing pressure there at that time as reported by Briggs (1975). The returns do reveal, however, that tautog started to leave Kismet reef for ocean waters in October and November. Migration was mostly to the west in the New York Bight.

Little can be said of the movements of tautog from Fire Island reef. Only 12 tags were returned from fish marked there: seven from the

Table 6. For Tautog Tagged At Kismet Reef, Relationship of Number Retaken At Same Site From Year to Year to Corresponding Total Number Retaken

Year tagged	Year retaken						
	1969	1970	1971	1972	1973	1974	1975
1969	222 (245)	24 (17)					
1970		238 (250)	13 (19)	0 (1)	1 (1)		
1971			85 (97)	3 (9)	2 (2)		
1972				53 (58)	14 (25)	0 (1)	2 (2)

tagging site, one each from Great South Bay, Kismet reef, Moriches Inlet and the ocean "off Fire Island, and one from an unknown location.

Of the tautog tagged at Kismet reef, the majority of those recovered were caught during the same year as tagged (Table 6). In addition, substantial proportions of those retaken in subsequent years were caught at that site. This indicates that tautog tend to return to the same relatively small area for several years.

Survival and Mortality

Most of the returns for tautog tagged at Kismet reef (524 of 533) and at Fire Island reef (9 of 12) came from anglers. Only six came from spear fishermen and five from commercial fishermen, while in one instance the method of capture was unknown. The data indicate that the harvest of tautog populations in these areas by means other than angling was of minor importance.

There were enough fish tagged and tags returned to serve as a basis for estimates of survival and mortality for the fish marked at Kismet reef. However, the design of the study (two kinds of tags used, tagging extending from May to December and a primary interest in population numbers and movements) led to problems. Many of the Petersen discs were shed and, while these fish could be recognized when recaptured by project personnel, it is doubtful that any anglers recognized them. Hence, the returns reported for tautog tagged from 1969 to 1971 were lower than they should have been, and the data for those years could not be used for estimating survival. In 1972, only the anchor tag was used, and the data for fish tagged before the fishing pressure there became heavy (i.e., fish tagged on or before October 1) could be analyzed by the methods outlined by Ricker (1958) to derive survival and mortality estimates (Table 7). Survival was estimated to be 46 per cent. The estimate of a

TABLE 7. ESTIMATED RATES OF SURVIVAL AND MORTALITY FOR TAUTOG TAGGED IN 1972

Item	Number or value
Fish tagged (through October 1)	
Total number	1,017
Recovered during tagging period	3
Number used for calculation	1,014
Fish recovered	
First year	37
Second year	17
Survival (per cent)	46
Mortality (per cent)	
Fishing	4
Natural	50
Total annual	54

TABLE 8. CALCULATED CHANGE IN TOTAL WEIGHT OF HYPOTHETICAL POPULATION OF 1,000 MALE AND 1,000 FEMALE TAUTOG SUSTAINING AN ANNUAL NATURAL MORTALITY OF 50 PER CENT*

Age (years)	Number of fish§	Weight in grams			
		Average†		Total	
		Male	Female	Male	Female
1	1,000	4	4	4,000	4,000
2	500	35	36	17,500	18,000
3	250	117	123	29,250	30,750
4	125	202	231	25,250	28,875
5	62+	314	370	19,625	23,125
6	31+	433	518	13,531+	16,187+
7	15+	560	672	8,750+	10,500+
8	7+	728	854	5,228+	6,133+
9	3+	897	1,050	3,503+	4,101+
10	1+	1,036	1,238	2,023+	2,417+

* Over 10-year period for fish 1 year old at start.
§ Figures represent number of each sex.
† After Cooper (1967).

total annual mortality of 54 per cent was comprised of 4 per cent fishing mortality and 50 per cent natural mortality. Using 50 per cent annual natural mortality and the weights at different ages given by Cooper (1967), Table 8 shows that the maximum biomass is reached when tautog are 3 years old (200 millimeters long for males and 190 millimeters for females).

DISCUSSION

The disparity in mean size between the tautog at the two reefs in the fall was probably the result of migration of the larger fish from the Kismet area. Olla et al. (1974) showed the larger tautog (250 millimeters

in length or larger) disappeared in late October from the bay in the vicinity of the Fire Island Coast Guard Station which is only about 6 kilometers west of Kismet reef. He attributed this phenomenon to migration. Later, Olla and Studholme (1975) stated that young tautog do not migrate offshore, but remain at their home sites. There also may have been an influx of juvenile tautog at Kismet reef in the fall.

Bigelow and Schroeder (1953) noted that the tautog fluctuates in abundance from year to year. Natural fluctuations and the smaller size of the fish tagged in 1969 probably account for much of the difference in the population estimates over the years at Kismet reef. Considering the small size of the reef at the time of the study (only 457 by 46 meters), a large tautog population existed there each year.

Olla et al. (1974) and Olla and Studholme (1975) indicated that large tautog migrated offshore during the period from October to winter, while juveniles remained through the winter at their home sites. The increase in tag returns from oceanic waters in October and November recorded during the present study supports this. The larger tautog from the Kismet reef appear to winter in the inshore waters of the northwestern corner of the New York Bight.

It is unfortunate that the data for all the years of tagging could not be used in making survival and mortality estimates. Fishing pressure was probably heavier, since it started earlier, in 1969, 1970 and 1971 than in 1972.[2] Fishing mortality was not high for the fish tagged in 1972 (only 4 per cent). In any case, based on the data derived for this population with respect to weight according to age and natural mortality, it would appear that tautog, to be harvested for the greatest total weight, should be taken at age III. Although Cooper (1966) stated that both sexes become mature at age III, there is some indication that females in New York waters may not mature until a year later. The present size limit in this State for tautog that may be bought, sold or offered for sale is 7 inches (178 millimeters). Assuming that the population studied is representative of that in New York waters generally, this limit affords little protection to the species, since it allows tautog to be trafficked in before the population reaches its greatest biomass (thus a waste of the potential of the resource) and before sexual maturity is attained. To assure that the females spawn at least once, it would be necessary to raise the size limit to at least 9 inches (228 millimeters). Also, since tag returns revealed the sport fishery to be the major harvester of tautog, the size limit should be applied to sport-caught fish as well as to those entering commerce.

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[2] In 1972 fishing for summer flounder was much better than it had been in the preceding years, and observations by project personnel indicated that fishing for tautog commenced later.

ADDENDUM

After this paper was written, a tautog that had been tagged on August 17, 1972 at Kismet reef was caught by an angler on November 2, 1976 at Cerebrus Shoal in Block Island Sound. It is rare for a marine fish to retain a tag over four seasons.

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DISTRIBUTION AND RELATIVE EXPLOITATION OF YELLOW PERCH TAGGED ON SPAWNING GROUNDS IN ONEIDA LAKE[1]

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ABSTRACT

Of 5,351 tags applied to spawning yellow perch at four sites in Oneida Lake from 1960 to 1973, 233 (4.4 per cent) were returned by anglers. The spawning run at each site consisted of perch which dispersed rapidly (within several weeks) to all parts of the lake, although a significantly greater proportion took up residence locally. The fish invariably returned to the same spawning ground in following years. The rate of tag return was positively related to size, which contributed to the greater recovery of females since they averaged larger than males among the fish tagged. Peak catches occurred in June and August. The annual survival of adult yellow perch was estimated from the tag returns to have been 56 per cent.

Very little is known about the dispersal of yellow perch (*Perca flavescens*) following spawning and their post-spawning distribution in large inland waters such as Oneida Lake (area=207 square kilometers). Muncy (1962) found that yellow perch tagged on the spawning grounds dispersed throughout a small estuarine system during the summer, and Mraz (1952) found that in Lake Michigan most summer recoveries (after May 31) of tagged perch were outside the tagging area. Spawning yellow perch were tagged nearly every year from 1960 to 1973 in Oneida Lake. Except for fish recaptured during subsequent spawning runs, almost all the tags returned were from fish taken by anglers. The primary purpose of this paper is to describe the spacial distribution of these angling recaptures. Additional observations on the temporal distribution of the tag returns from anglers, mortality rates and relative rates of exploitation, and on the homing of spawning yellow perch based on recaptures in nets, are presented.

METHODS

Oneida Lake is a large, shallow (mean depth=6.8 meters) eutrophic lake in central New York. Yellow perch were captured in trap nets during the spawning run in late April and early May and were marked with either a single- or double-barb wire dart or a plastic spaghetti tag. The fish were measured to the nearest 2.5 millimeters, tagged and released where captured. Anglers were encouraged to return tags through publicity releases and personal contact. Self-addressed tag-return envelopes were made available at boat-launching sites and boat liveries.

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-17-R. John Forney reviewed the manuscript. Alice Klock compiled the data from anglers and drafted the illustration.

If the information accompanying a returned tag was not complete, a follow-up was made by mail provided the return address of the angler was available. A few tag returns could not be narrowed down as to time and/or place of capture, and 4 per cent of the fish were not sexed when tagged; thus totals in the tables are not always additive. To facilitate analysis of tag-return data, the lake was divided into six arbitrary areas of equal size. Since fishing pressure varied between these areas, the tag returns were adjusted by using a May-October boat count for each area for 1958-59 (Forney, 1963). This adjustment assumes that angling pressure throughout the year was distributed similarly to that from May to October and that the catch per boat was the same in all areas.

The formula

$$S_1 = \frac{R_{12} + R_{13} \ldots + R_{1n}\, M_2}{R_{22} + R_{23} \ldots + R_{2n}\, M_1} \times 100$$

was used to estimate the percentage of survival (S_1) during the first year after the initial tagging (Forney, 1961). Recaptures of fish tagged in the first year and recovered in the second and subsequent years are designated

Figure 1. Map of Oneida Lake showing tagging sites (X) and areas used in summarizing tag recoveries.

$R_{12} \ldots R_{1n}$, while $R_{22} \ldots R_{2n}$ represent fish tagged in the second year and recovered in the second and later years. M_1 and M_2 are the numbers of tagged fish released in years 1 and 2, respectively. The tagging sites and areas used in analyzing returns are shown in Figure 1.

RESULTS AND DISCUSSION

The data are presented and discussed separately with respect to spacial distribution, homing, exploitation, temporal distribution and survival.

Spacial Distribution

A total of 5,351 yellow perch 155 to 328 millimeters long were tagged at the four sites from 1960 through 1973. Of these, 233 (4.4 per cent) were returned by anglers (Table 1). Most were fish tagged at Site 1 in Area I and at Sites 2 and 3 in Area V. The great majority of the returned tags came from fish caught in Areas I (53), IV (46) and V (45), suggesting that perch tended to remain near the area where they had been tagged (Table 2). Although fishing pressure was greater in these

Table 1. Size and Number of Yellow Perch Tagged At Four Sites in Oneida Lake and Number of Tags Returned By Anglers, According to Sex, 1960-1973

Year	Site	Mean length (millimeters)			Number tagged*			Tags returned*		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
1960	1	255	284	260	119	24	178	3	4	11
	2	247	266	257	97	107	204	6	10	16
	3	252	289	274	170	253	423	10	12	23
1961	2	..	273	273	0	9	39	..	2	5
	3	266	272	269	20	27	134	6	6	22
	4	255	271	260	213	85	298	6	8	14
1962	1	260	258	260	281	97	378	12	1	13
	2	232	270	236	196	22	242	10	2	14
	4	226	261	237	271	130	401	10	5	15
1963	1	244	263	249	436	144	580	11	6	18
1964	1	247	267	254	237	121	358	5	11	16
1965	1	249	262	252	359	134	493	18	4	23
1966	1	249	269	254	307	93	400	12	5	17
1967	1	252	277	259	216	87	303	4	3	7
1968	1	251	267	255	72	24	96	2	1	3
1970	2	228	250	231	194	30	224	4	3	7
1971	2	250	271	253	264	36	300	7	1	8
1973	2	226	251	229	236	26	300	1	0	1
Subtotal	1	250	266	254	2,027	724	2,786	67	35	108
	2	236	263	241	987	230	1,309	28	18	51
	3	253	287	274	190	280	557	16	18	45
	4	239	265	247	484	215	699	16	13	29
Total		245	270	252	3,688	1,449	5,351	127	84	233

* Because some of the fish were not sexed when tagged, the totals are not always additive.

TABLE 2. NUMBER OF YELLOW PERCH TAGGED AND RECOVERED IN ONEIDA LAKE, ACCORDING TO SITE WHERE TAGGED AND AREA WHERE RECOVERED, AND CORRESPONDING VALUES AS ADJUSTED FOR ANGLING PRESSURE IN EACH AREA, 1960-1973

Site where tagged	Area where recovered							Chi-square
	I	II	III	IV	V	VI	Total	
	Number recovered							
1	39	11	5	31	3	9	98	xxx
2	6	7	1	7	20	7	48	xxx
3	4	4	3	4	18	9	42	xxx
4	4	1	6	4	4	9	28	xxx
Total	53	23	15	46	45	34	216	xxx
	Adjusted number*							
1	7.2	4.3	2.0	4.7	0.7	2.0	20.9	8.03
2	1.1	2.7	0.4	1.1	4.9	1.6	11.8	6.62
3	0.7	1.6	1.2	0.6	4.4	2.0	10.5	5.61
4	0.7	0.4	2.4	0.6	1.0	2.0	7.1	2.81
Total	9.7	9.0	6.0	7.0	11.0	7.6	50.3	2.04
Number of boats§	5,410	2,567	2,530	6,615	4,123	4,518	xxx	xxx

* Number recovered divided by number of boats and multiplied by 1,000.
§ According to Forney (1963).

areas, the adjusted numbers of perch tags returned per boat still differed significantly from the expected distribution (i.e., $\frac{1}{6}$ of the tags in each area) for the perch tagged at Sites 1, 2 and 3 (chi-square = 5.61 to 8.03, d.f. = 1, $P < 0.05$; Table 2), but not for the perch tagged at Site 4 (chi-square = 2.81). For all the tagging sites combined, however, the distribution of tag returns did not differ significantly from that expected from the null hypothesis (chi-square = 2.04, d.f. = 1) even though no fish were tagged in three of the areas.

The highest adjusted rate of tag return for the fish tagged at each of the four sites was from the area where they had been tagged (Table 2). Since the perch have been shown to have redistributed themselves somewhat throughout the lake, it seemed possible that part of this greater catch in the tagging area was due to anglers catching the fish soon after tagging and spawning. The numbers of tagged perch caught in April and May of the year tagged were determined (Table 3). For all the tagging sites combined, only 10 (38.5 per cent) of 26 perch caught were from the area where they had been tagged. This was essentially identical to the 83 (38.4 per cent) of 216 recoveries in all months that were taken in the area where tagged (Table 2) and indicates that perch are very rapidly redistributed after spawning. The spawning run at each site consisted of fish which return to all parts of the lake, although a larger proportion take up subsequent residence locally than in any other one area. There

Table 3. Number of Yellow Perch Tagged During April and May in Oneida Lake and Caught During Same Months of Same Year, According to Site Where Tagged and Area Where Recovered, 1960-1973

Site where tagged	Area where recovered						Total	
	I	II	III	IV	V	VI	Area where tagged	Other areas
1	4	1	2	5	1	1	4	10
2	..	..	..	..	3	2	3	2
3	..	..	..	..	..	1	0	1
4	..	..	3	..	..	3	3	3
Total	4	1	5	5	4	7	10	16

Table 4. Number of Tagged Male and Female Yellow Perch Recovered in Oneida Lake According to Area Where Recovered, 1960-1973

Sex	Area where recovered						Total
	I	II	III	IV	V	VI	
Male	36	13	7	21	22	17	116
Female	13	9	6	23	15	13	79
Total	49	22	13	44	37	30	195

were no spacial sub-populations, as in Douglas Lake in Michigan (Rodeheffer, 1941).

The numbers of each sex that were tagged at each site each year are given in Table 1. More males than females were tagged at Site 1 (16.8 to 33.8 per cent females) and Site 4 (28.5 to 32.4 per cent), while females were predominant in the samples tagged at Site 3 (57.5 to 59.8 per cent) and variable at Site 2 (9.9 to 52.5 per cent). Differences in sex ratio in the sample tagged did not bias the distribution of tag recoveries, since the proportions of males and females recovered in the six areas were not significantly different (chi-square=6.95, d.f.=5; Table 4). Thus, in years such as 1960 to 1962 when perch were tagged at several sites, the fish were redistributed fairly evenly throughout the lake.

Homing

Perch tagged during the spawning period in April at Sites 1 and 2 were recaptured in trap nets set at the same locations in subsequent years, 34 originally tagged at Site 1 and 14 at Site 2 being so recaptured 1 to 5 years after release. None was recaptured at a spawning site other than the one where it had been tagged. That none of the perch tagged at Sites 3 and 4 during April were recaptured in these nets may indicate that fish netted in these two areas were intercepted enroute to another area.

Spawning was especially unlikely at Site 4, since the bottom there is exclusively bare sand.

Homing appeared to be strong in both sexes. The samples of tagged fish recaptured in the trap nets at Sites 1 and 2 contained a smaller proportion of females than did the groups originally tagged at those sites (17.4 vs. 26.3 per cent and 14.3 vs. 18.9 per cent, respectively), a difference probably due to the greater vulnerability of males to trap nets during the spawning season.

RELATIVE EXPLOITATION

Because the percentage of tags recovered that were returned is unknown, no conclusions can be drawn about the actual rate of exploitation of adult yellow perch. The over-all rates of tag return were 3.4 per cent for males and 5.8 per cent for females (Table 5). Since, except for

TABLE 5. PERCENTAGE OF TAGS RETURNED AND MEAN NUMBER OF DAYS BETWEEN TAGGING AND RECAPTURE FOR MALE AND FEMALE YELLOW PERCH TAGGED IN ONEIDA LAKE, 1960-1973

Site	Percentage of tags returned			Mean number of days between tagging and recapture		
	Male	Female	Total	Male	Female	Total
1	3.3	4.8	3.9	573	430	559
2	2.8	7.8	3.9	334	321	310
3	8.4	6.4	7.7	294	205	199
4	3.3	6.1	4.2	131	251	181
Total	3.4	5.8	4.4	436	336	392

the fish tagged in 1962 at Site 1, the length of the females tagged was greater than that of the males (Table 1), it appeared that the rate of exploitation was related to size. To test this possibility, the number of fish tagged at each site and the number recovered by anglers during the following year only were determined for six size groups (Table 6). For all sites combined, the rate of tag recovery was significantly different for perch of various sizes (chi-square = 20.14, d.f. = 1) and increased from 1.7 per cent for 203-228 millimeter fish to 8.5 per cent for 305-329 millimeter fish. The relatively high rate of capture for 178-202 millimeter fish was due to the recovery of five perch tagged at Site 1. Over-all the larger size of females contributed to greater vulnerability in Oneida Lake, although Muncy (1962) found no angler selectivity for larger yellow perch.

For all size groups combined, the rate of tag recovery from the various tagging sites was also significantly different (chi-square = 19.66, d.f. = 1) because of the very high rate (4.8 per cent) at Site 3 (Table 6). Although females were predominant in the sample tagged at Site 3, the rate of tag recovery for males tagged at that site in 1960 and 1961 ex-

Table 6. Number of Yellow Perch Tagged At Each Site in Oneida Lake and Recaptured During the Following Year, According to Size At Time of Tagging, 1960-1973

Site	Size group (millimeters)						Total
	178-202	203-228	229-253	254-278	279-304	305-329	
Site 1							
Number tagged	56	302	1,023	1,034	343	36	2,794
Number recaptured	5	4	16	19	7	2	53
Per cent recaptured	..	..	..	..	..	..	1.9
Site 2							
Number tagged	92	334	375	352	105	14	1,272
Number recaptured	1	6	7	7	0	1	22
Per cent recaptured	..	..	..	..	..	..	1.7
Site 3							
Number tagged	4	12	81	218	220	31	566
Number recaptured	0	0	1	14	7	5	27
Per cent recaptured	..	..	..	..	..	..	4.8
Site 4							
Number tagged	22	123	221	213	93	13	685
Number recaptured	0	3	7	4	5	0	19
Per cent recaptured	..	..	..	..	..	..	2.8
Total							
Number tagged	174	771	1,700	1,817	761	94	5,317
Number recaptured	6	13	31	44	19	8	121
Per cent recaptured	3.4	1.7	1.8	2.4	2.5	8.5	2.3

ceeded that for females (5.9 vs. 4.7 per cent and 30.0 vs. 22.2 per cent, respectively), indicating that factors other than sex and size produced the relatively high rate of recovery of tags from this site. The tagging of only two groups of exceptionally vulnerable perch at Site 3 in 1960 and 1961 was probably responsible, since the highest rates of recovery for fish tagged at the other sites also applied to those tagged in 1960 (6.2 and 7.8 per cent for Sites 1 and 2, respectively) and 1961 (12.8 and 4.7 per cent for Sites 2 and 4, respectively) as shown in Table 1. Differences in recovery rates for the two sexes at Sites 1, 2 and 4 were not great, although returns were lowest from the two sites (1 and 2) at which the greatest proportion of the fish tagged were males.

Temporal Distribution

The monthly distribution of tag recoveries indicated that most of the yellow perch taken were caught from May through September, with the peak catch being made in June and August (Table 7). The December through March catch was 18.2 per cent of the total, which is consistent with the creel census of Grosslein (1961) which showed that from 5 to 20 per cent of the yearly catch of yellow perch in Oneida Lake was made in the winter.

TABLE 7. MONTHLY DISTRIBUTION OF TAGGED YELLOW PERCH CAUGHT BY ANGLING IN ONEIDA LAKE ACCORDING TO SITE WHERE TAGGED, 1960-1973

Month	Site where tagged				Total
	1	2	3	4	
January	7	5	4	4	20
February	5	4	4	0	13
March	1	3	0	1	5
April	2	0	0	1	3
May	13	5	1	5	24
June	20	5	6	5	36
July	13	5	4	3	25
August	24	10	12	3	49
September	17	6	5	1	29
October	7	3	2	4	16
November	0	1	1	0	2
December	1	0	2	0	3
Total	110	47	41	27	225

TABLE 8. NUMBER OF TAGGED YELLOW PERCH CAUGHT BY ANGLING IN ONEIDA LAKE IN VARIOUS YEARS FOLLOWING TAGGING, ACCORDING TO YEAR IN WHICH TAGGED, 1960-1973

Year tagged	Year following tagging								Total
	1	2	3	4	5	6	7	8	
1960	29	14	4	1	1	..	..	..	49
1961	25	13	2	..	..	..	..	..	40
1962	30	8	2	1	1	..	..	..	42
1963	5	5	3	2	3	..	..	..	18
1964	8	6	..	..	1	..	..	1	16
1965	9	7	1	3	2	1	..	..	23
1966	9	..	3	3	2	..	..	..	17
1967	2	1	..	3	..	..	..	..	6
1968	2	..	..	..	1	..	..	..	3
1970	3	..	3	1	..	..	..	..	7
1971	4	2	1	1	..	..	..	..	8
1973	1	..	..	..	..	..	..	..	1
Total	127	56	19	15	11	1	0	1	230

Sexual differences in vulnerability to angling undoubtedly contributed to the fact that tagged males had been at large longer, on the average, than tagged females before being recaptured (Table 5). The number of days between tagging and recapture ranged from four to 2,478, both extremes applying to female perch.

ANNUAL SURVIVAL

Although a majority (55 per cent) of the tagged perch that were recovered were recaptures during the year in which they had been tagged, and an additional 25 per cent the following year, substantial numbers were recovered through the fifth year (Table 8). Annual survival for

Table 9. Number of Yellow Perch Tagged in Oneida Lake and Caught by Anglers in Various Years From 1960 to 1974

Year	Number tagged	Year of recapture															Total
		1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	
1960	805	29	14	4	1	1	..	..	..	..	..	..	..	..	..	..	49
1961	471	..	25	13	2	..	..	..	..	..	..	..	..	..	..	..	40
1962	1,021	..	..	30	8	2	1	1	..	..	..	..	..	..	..	..	42
1963	580	..	..	..	5	5	3	2	3	..	..	..	..	..	..	..	18
1964	358	..	..	..	..	8	6	..	..	1	..	..	1	..	..	..	16
1965	493	..	..	..	..	..	9	7	1	3	2	1	..	..	..	..	23
1966	400	..	..	..	..	..	..	9	..	3	3	2	..	..	..	..	17
1967	303	..	..	..	..	..	..	..	2	1	..	3	..	..	..	..	6
1968	96	..	..	..	..	..	..	..	..	2	..	..	..	1	..	..	3
1969	0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0
1970	224	..	..	..	..	..	..	..	..	..	..	3	..	3	1	..	7
1971	300	..	..	..	..	..	..	..	..	..	..	..	4	2	1	1	8
1972	0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0
1973	300	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1
Total	5,351	29	39	47	16	16	19	19	6	10	5	9	5	6	3	1	230

the first year after tagging (S_1), as calculated from the returns shown in Table 9 for the fish tagged during the first nine years[2], ranged from 29 per cent for perch tagged in 1960 to 100 per cent for perch tagged in 1966. The unweighted mean survival was 56 per cent, which corresponds closely to the survival of 64 per cent for adult perch derived from population estimates made by mark-and-recapture in 1969, 1971 and 1973 (Clady, 1976). Yellow perch in Oneida Lake were taken by anglers for up to seven years after tagging. Although Stebo (1972) found that small T-dart tags were retained well by perch for less than 1 year, some tags may have been lost over the longer periods in the present study and thus may account for the slightly poorer survival estimated from the tag recoveries.

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[2] When this paper was written, it was assumed that any further returns for perch tagged in these years would be negligible, whereas for those tagged in subsequent years significant recoveries could be expected.

EPIBENTHIC INVERTEBRATES OF CROTON BAY IN THE HUDSON RIVER[1]

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ABSTRACT

An 8-month survey of the epibenthic fauna of Croton Bay in the Hudson River (N.Y.) was conducted. Modified Mason traps were efficient in sampling many highly mobile or sessile organisms that are difficult to capture with conventional gear. Organisms of at least 39 genera were taken including four amphipods, two isopods, two decapods, a complex of chironomids, three gastropods and several polychastes. In addition, the setting patterns of the barnacle, *Balanus improvisus,* and the mussel, *Congeria leucophaeta,* are described. The benthic organisms collected from Croton Bay were representative of the fauna present in similar habitats of a large portion of the Tappan Zee and Haverstraw Bay which is typically estuarine.

An 8-month survey of the epibenthic organisms of Croton Bay was conducted as part of a study to identify the invertebrate fauna of the shallows of the mid- and lower Hudson River (N.Y.) and to assess the impact of the landfill at Croton Point on the estuarine biota. The study was made to supplement previous benthic surveys in the area (Ristich, 1972; Williams et al., 1975). Setting data for *Balanus improvisus* and *Congeria leucophaeta* are also included.

MATERIALS AND METHODS

Samples were taken with modified Mason traps (Figure 1), 13- x 6-inch cylinders of heavy-gauge wire mesh with 0.5-inch openings (Mason et al., 1967; Anderson and Mason, 1968). The traps were filled through a hinged door with 3- to 4-inch bluestone and were suspended about 1 inch from the bottom at the locations shown in Figure 2. Stations 1, 2, 4 and 5 were just offshore, while Stations 3 and 6 were located in a small channel of the adjoining marsh. All traps were positioned so that they remained below water at low tide. Traps were placed on April 2, 1974, and sampling was done at approximately monthly intervals until December 6, 1974. Three traps were used at each station. To begin with, Traps 1 and 2 were placed, and both were sampled after 1 month, at which time Trap 1 was removed and Trap 3 was placed. After another month, Traps 2 and 3 were sampled, Trap 2 was removed and Trap 1, which had been cleaned and refilled with new substrate, was placed. This procedure was followed throughout the time sampling was

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carried on. Each trap remained in place for a period of 2 months during which it was sampled twice. The setting patterns of *Balanus* and *Congeria* could be followed with this procedure.

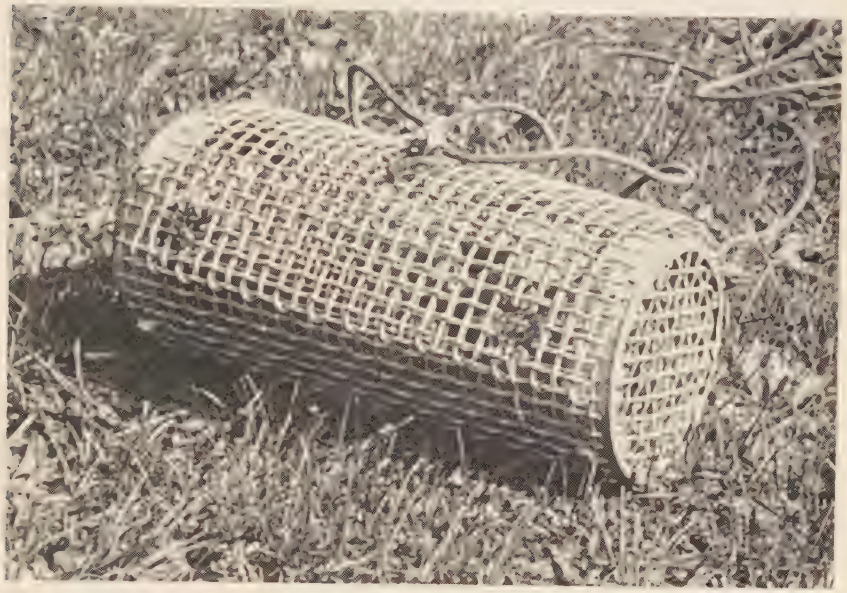

Figure 1. The modified Mason trap as used in this study.

Figure 2. Croton Point and Croton Bay showing trap locations and landfill area.

When sampled, each trap was lifted from the water and placed in a large tub. The tub was filled with water and the trap was shaken vigorously. This procedure removed a high percentage of the organisms. The trap was then placed in another tub containing clean water, while the water from the first tub was poured through two nylon screens of mesh sizes 1300 nm and 850 nm, respectively. The trap was removed from the second tub and that water was also poured through the nylon screens. A second tub was necessary because some slower moving organisms, or larger organisms (e.g., *Rhithropanopeus*), often took several minutes to vacate the trap. The traps were replaced and the samples were fixed in 7.5 per cent buffered formalin for return to the laboratory for sorting. Organisms were sorted under a dissecting microscope, and ovigerous females and young were recorded. Traps that had been removed after the 2-month period were disassembled and the number of barnacles and *Congeria* set were counted.

Temperature measurements were taken at each station, and salinity readings from a nearby plankton-sampling station were used.

RESULTS AND DISCUSSION

The Mason trap proved to be an excellent tool for sampling invertebrates in Croton Bay, and it was especially good for sampling some of the more mobile epibenthic organisms, such as amphipods, and the sessile organisms, neither of which are sampled well be conventional benthic grabs.

Salinity and Temperature

Water off Croton Point was fresh during most of the year. Saline water did not intrdue into Croton Bay until late summer, and salinity reached a maximum of 5.5 ppt in September (Table 1). Temperature variations within Croton Bay were typical of the estuary. A maximum of 25.3° C. and a minimum of 3.9° C. were recorded in August and December, respectively.

Table 1. Salinity and Temperature Readings in Croton Bay at the End of Each of the Seven Sampling Periods in 1974

Date	Period	Salinity (ppt)	Temperature (° C.)
April 2	(traps placed)	0.0	6.1
May 8	I	0.0	12.6
June 6	II	0.0	20.1
July 1	III	0.0	20.7
August 10	IV	2.6	25.3
September 15	V	5.5	22.5
October 23	VI	4.5	13.5
December 6	VII	0.0	3.9

FAUNA

Organisms belonging to at least 39 genera were found in the Mason traps during the seven sampling periods, 18 being identified to species and 12 to genus. Turbellarians, nematodes, oligochaetes and leeches were also found but were not identified further. All the groups represented in the collections are listed in Table 2, and the more common species are discussed.

Four genera of amphipods were found in the traps, a complex of gammarids including *Gammarus tigrinus* and *G. daiberi* being the most common (Table 3). These were found in great numbers during all sampling periods, reaching a maximum of 50,990 in August for the six stations combined. Most of the gammarids were found at the four stations in the bay, with fewer occurring at Stations 3 and 6 in the marsh inlet. Ovigerous females were found at all stations from May through September. This 5-month reproductive period is slightly shorter than that given for these gammarids by Bousfield (1973).

The next most abundant amphipod was *Corophium lacustre,* large numbers of which were recorded from August to December. Ovigers were present during August and September. *Melita nitida* was common during the same period as *Corophium* with a peak of 964 individuals being recorded in August. Ovigers were present only in samples taken during August. Both *Corophium* and *Melita* are estuarine (Bousfield, 1973) and become abundant in the late summer. They are more abundant earlier in the year farther downriver (Ristich et al., 1973) and probably move into Croton Bay as the salinity increases.

Few specimens of *Leptocheirus plumulosus* were found, although large numbers had been taken in benthic grabs in the same area during a previous effort (Ristich, 1972). This could indicate a large decline in the population of this organism. More likely possibilities, however, are an aversion to the traps by this species or an ability to remain within its tubes during the washing process.

The isopod, *Cassidinidea lunifrons,* was found from August to December primarily in the bay traps. It was most abundant during August, the only period during which ovigers were collected.

Cyathura polita was collected during all periods except May. It, too, was most abundant in the bay traps. Ovigers were collected during June and July, indicating a reproductive period similar to that observed by Burbanck (1962).

The mud crab, *Rhithropanopeus harrisii,* was the only brachyuran decapod collected. It was numerous in the bay traps and was common from June to October. Like most crabs it probably becomes inactive and burrows into the bottom during periods of low temperatures. Ovigers were found during July, August and September. The shrimp, *Palaemo-*

Table 2. Organisms Found in the Mason Traps in Croton Bay*

Coelenterata
  Hydrozoa
    Cordylophora lacustris Allman
Platyhelminthes
  Turbellaria
    Planariidae
  Rhabdocoela
Nematoda
Nematomorpha
Annelida
  Polychaeta
    Hypaniola florida (Hartman) [=*H. grayi*]
    Polydora sp.
    Scolecolepides viridis (Verrill)
  Oligochaeta
  Hirundinea
Mollusca
  Gastropoda
    Hydrobia sp.
    Physa heterostropha (Say)
    Amnicola limosa (Say)
    Tenellia fuscata (Gould)
  Pelecypoda
    Congeria leucophaeta Conrad
Arthropoda
  Insecta
    Chironomidae
      Tanypus sp.
      Procladius sp.
      Xenochironomus (Anceus) sp.
      Parachironomus sp.
      Chironomus sp.
      Goeldichironomus sp.
      Einfeldia sp.
      Dicrotendipes sp.
      Polypedilum sp.
      Cricotopus sp.
    Tanytarsini
    Tipulidae
  Odonata
  Crustacea
    Cumacea
      Almyracuma proximoculi (Jones)
    Amphipoda
      Gammarus daiberi Busfield
      Gammarus tigrinus Sexton
      Corophium lacustre Vanhoffen
      Melita nitida Smith
      Leptocheirus plumulosus Shoemaker
    Isopoda
      Cyathura polita (Stimpson)
      Cassinidea lunifrons (Richardson)
    Cirripedia
      Balanus improvisus Darwin
    Decapoda
      Palaemonetes pugio Holthius
      Rhithropanopeus harrissi (Gould)

* Where no species is given, greatest extent of identification is indicated.

TABLE 3. ABUNDANCE OF COMMON INVERTEBRATES FOUND IN THE MASON TRAPS IN CROTON BAY DURING THE SEVEN SAMPLING PERIODS*

Organism	Period							Total
	I	II	III	IV	V	VI	VII	
Gammarus	7,628	6,531	7,844	50,990	22,217	5,797	5,907	106,914
Corophium	4	23	21	5,071	3,870	2,558	4,531	16,078
Melita	2	5	13	964	170	353	765	2,272
Leptocheirus	0	1	1	0	7	2	30	41
Cassidinidea	0	1	0	37	14	6	3	61
Cyathura	0	49	27	34	22	5	64	201
Rhithropanopeus	3	45	85	91	68	87	1	380
Palaemonetes	0	0	0	7	27	4	0	38
Chironomids	79	10,573	8,720	1,840	2,767	1,160	1,814	26,953
Hydrobia	0	15	246	42	196	22	17	538
Physa	7	22	15	33	44	4	6	131
Amnicola	0	63	28	5	31	16	1	144
Hypaniola	0	10	3	165	701	254	550	1,683
Oligochaetes	40	3,632	438	398	2,162	555	445	7,670
Balanus	..	0	32	8,781	9,124	1,698	0	19,524
Congeria	..	0	0	9	104	15	0	128

* Numbers represent total for all six stations combined, except that for *Balanus* and Congeria they represent number per trap.

netes pugio, was not common but was found during June, July and August. No ovigers of this species were collected.

The barnacle, *Balanus improvisus,* was present from July to October in all the bay traps. The major setting occurred in July and August when approximately 8,000 to 10,000 barnacles set per trap (Figure 3). This setting period corresponds well with plankton data taken near Croton Point which showed a large decrease in barnacle cypris larvae in the samples taken in August (William E. Hopkins, personal communication).

A complex of chironomids was found in samples from all stations. Chironomids were most abundant at the two stations in the marsh inlet. The genera identified are given in Table 2 together with other insect larvae.

The mussel, *Congeria leucophaeta,* is the only bivalve common to the Croton Point area. It is present in large numbers wherever a sufficiently firm substrate exists. *Congeria* were found in traps removed in August, September and October, with a peak average of 104 per trap in Sep-

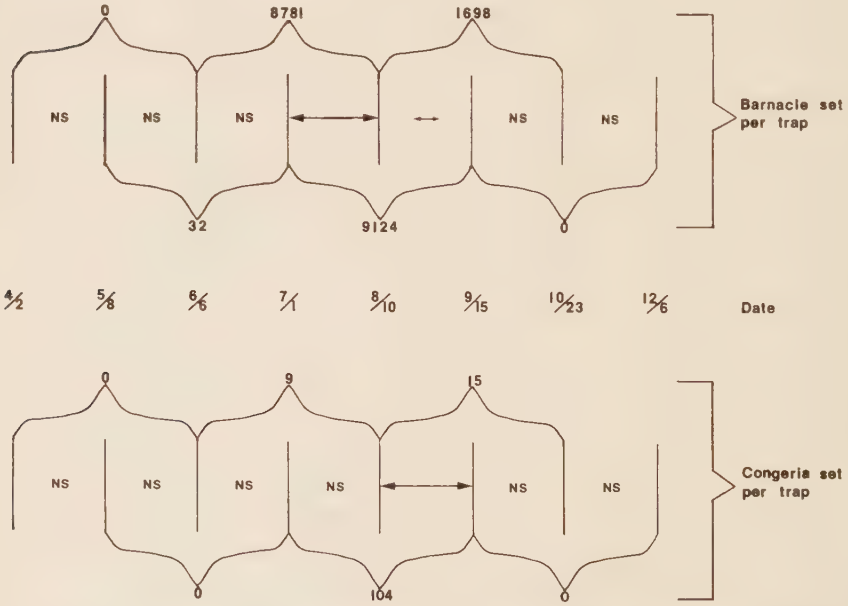

Figure 3. Setting patterns of the barnacle, *Balanus improvisus,* and the mussel, *Congeria leucophaeta.* Double-pointed arrow indicates major setting period; NS represents little or no set. The overlapping brackets for the numbers recorded for the successive dates reflect the fact that the traps at each station were in operation on a staggered basis for 2-month periods and were examined for *Balanus* and *Congeris* at the end of each period.

tember. The peak setting time was between August 10 and September 15 (Figure 3). *Hydrobia* sp. was the most common gastropod found and was most numerous in the marsh inlet traps from June to December. *Physa heterostropha* was found exclusively in the marsh inlet traps during all periods. Large numbers of both egg masses and adult *Physa* were noted in tidal pools and ponds in May, implying that this may be their reproductive period. *Amnicola limosa* was also found in the traps from May to October.

Hypaniola grayi was the most common polychate collected. It was present in small numbers in June and July and was abundant for the remainder of the study period. *Scolecolepides viridis* and *Polydora* sp. were also collected in small numbers.

Oligochaetes were found during all sampling periods. A peak abundance of 3,632 was observed in June, when these organisms were most common at the marsh inlet stations.

CONCLUSIONS

The results of this study indicate tht there is little stress imposed of the epibenthic community by the Croton Point landfill. Comparisons of these data and those presented by other investigators (Ristich, 1972; Ristich et al., 1973; Williams et al., 1975) show that the fauna collected in the Mason traps is representative of the organisms of the general Tappan Zee-Haverstraw Bay area, which are typically estuarine.

The Mason trap is an excellent tool for sampling certain types of epibenthic organisms. Large numbers of organisms normally difficult to sample using conventional grabs can be obtained with relative ease. However, it must be recognized that use of the Mason trap or any similar device is, in reality, assessing the potential rather than the actual populations in an area. The use of artificial substrates as a sampling tool can result in providing habitats that do not exist under natural conditions. When this is done, species that normally cannot survive can thrive. An example of this is the barnacle. Without the Mason trap, the proper substrate necessary for their setting might not have been present in the study area. Therefore, work with artificial substrates should be carried out in conjunction with studies under actual conditions.

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Errata

In the July 1975 issue (Vol. 22, No. 2), the bear range in the Adirondack region was given as 12,311 square miles. This, however, represents the range in New York State as a whole. The correct figure for the Adirondack region is 9,283 square miles.

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